MATRIKS KOMENTAR ASESOR DAN HASIL REVISI

Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills

Revisi Asesor 1	Revisi Asesor 2	Hasil Revisi
R1-1. Judul terlalu definitif karena kata "outweighs"; pertimbangkan judul yang lebih hati-hati, yaitu "Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills."	R2-1. Judul "outweighs" terlalu konklusif untuk desain cross-sectional dan konteks spesifik; gunakan judul yang menekankan perbandingan, bukan superioritas.	**Asesor 1:** Judul telah direvisi menjadi "Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills" agar menekankan perbandingan dan tidak menyiratkan superioritas. **Asesor 2:** Judul telah diubah menjadi "Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills" untuk menegaskan fokus perbandingan, bukan superioritas.
R1-2. Akui bahwa analisis SEM menggunakan sampel relatif kecil dan bahwa model perlu ditafsirkan sebagai preliminary/exploratory.	R2-2. Naskah mencampur British dan American English; pilih satu ragam dan gunakan konsisten (misalnya analysed/modelling atau analyze/memorized).	**Asesor 1:** Abstrak telah menambahkan pengakuan bahwa analisis SEM menggunakan sampel yang relatif kecil. Temuan model dinyatakan sebagai bukti awal yang bersifat preliminary dan exploratory, bukan sebagai kesimpulan definitif. **Asesor 2:** Naskah telah disunting menggunakan satu ragam bahasa Inggris secara konsisten, yaitu American English, termasuk ejaan, istilah, dan bentuk kata kerja.
R1-3. Ubah "factor loadings above 0.50" menjadi "factor loadings of 0.50 or higher" karena satu loading tepat 0.50.	R2-3. "Aims and scope of paper" kurang alami untuk abstrak empiris; ganti dengan "Purpose" atau "Objective", kecuali diwajibkan template jurnal.	**Asesor 1:** Frasa pada abstrak telah diperbaiki menjadi "factor loadings of 0.50 or higher" agar sesuai dengan nilai loading terendah yang tercantum pada tabel. **Asesor 2:** Label "Aims and scope of paper" telah diganti menjadi "Purpose" agar lebih alami untuk abstrak penelitian empiris.
R1-4. Istilah "dominant" dan "supporting" terlalu kuat untuk desain cross-sectional; gunakan "was more strongly associated with critical thinking within the estimated model."	R2-4. Ganti "Result" menjadi "Results" karena paragraf melaporkan beberapa temuan.	**Asesor 1:** Ungkapan "dominant" dan "supporting" telah diganti dengan pernyataan yang lebih proporsional, yaitu bahwa mathematical self-efficacy "was more strongly associated with critical thinking within the estimated model". **Asesor 2:** Label "Result" telah diperbaiki menjadi "Results" karena bagian tersebut menyajikan beberapa temuan penelitian.
R1-5. Karena studi korelasional cross-sectional, kata "effects" dapat menyiratkan kausalitas. Gunakan "associations", "relationships", atau "predictive contributions" secara konsisten.	R2-5. Selaraskan keywords dengan istilah pada judul dan teks: "Learning motivation" dan "mathematical self-efficacy".	**Asesor 1:** Penggunaan istilah kausal telah disesuaikan dengan desain korelasional cross-sectional. Naskah menggunakan istilah "relationships", "associations", dan "predictive contributions" untuk menggambarkan hubungan antarvariabel secara lebih hati-hati. **Asesor 2:** Keywords telah diselaraskan dengan terminologi judul dan isi naskah, yaitu "Learning Motivation" dan "Mathematical Self-Efficacy".
R1-6. Jelaskan cara pemilihan acak dilakukan (random-number generator, undian, atau nomor identitas) dan apakah ada peserta menolak/tidak lengkap datanya.	R2-6. Dukung pernyataan umum tentang kesulitan berpikir kritis dengan studi empiris, asesmen nasional, atau konteks pendidikan lokal.	**Asesor 1:** Prosedur simple random sampling telah dijelaskan: setiap siswa diberi nomor identifikasi, pemilihan dilakukan menggunakan prosedur angka acak berbantuan komputer, dan seluruh siswa terpilih menyelesaikan pengumpulan data. **Asesor 2:** Pernyataan mengenai kesulitan berpikir kritis telah diperkuat dengan rujukan penelitian empiris yang relevan dengan pemecahan masalah matematika dan konteks pendidikan.
R1-7. Berikan justifikasi ukuran sampel terhadap kompleksitas CFA/SEM, misalnya power analysis, rasio parameter-sampel, atau pengakuan eksploratif.	R2-7. Perbaiki sitasi "Farah Deeba, Sana Hafeez, Shazia Noureen" ke format author-date dan lengkapi "et al., 2024" dengan penulis utama; cocokkan dengan daftar pustaka.	**Asesor 1:** Ukuran sampel telah dijelaskan sebagai keterbatasan penelitian. Analisis CFA/SEM dan interpretasi model ditempatkan sebagai analisis awal/eksploratif sehingga hasilnya tidak digeneralisasi secara berlebihan. **Asesor 2:** Sitasi yang sebelumnya belum sesuai telah diperbaiki ke format author–date. Nama penulis dan tahun publikasi telah dicocokkan dengan entri daftar pustaka.
R1-8. Jelaskan persetujuan orang tua/wali, assent siswa, serta persetujuan atau pengecualian komite etik.	R2-8. Beri sitasi langsung untuk gap penelitian; jelaskan studi mana yang meneliti variabel secara terpisah dan mana yang belum membandingkan kontribusi unik dalam satu model.	**Asesor 1:** Prosedur etika penelitian telah dijelaskan, meliputi izin sekolah, persetujuan tertulis orang tua/wali, assent siswa, serta keterangan mengenai ketentuan persetujuan komite etik formal di institusi. **Asesor 2:** Research gap telah diperjelas dengan dukungan sitasi yang menunjukkan penelitian terdahulu mengenai motivasi dan self-efficacy serta kebutuhan membandingkan kontribusi keduanya dalam satu model.

Revisi Asesor 1	Revisi Asesor 2	Hasil Revisi
R1-9. Laporkan jumlah item, sumber/pengembangan, contoh item, arah penskoran, reverse coding item negatif, dan reliabilitas khusus kuesioner motivasi.	R2-9. Jelaskan alasan teoretis pemilihan Teorema Pythagoras: representasi, pembuktian, pemilihan strategi, transfer konteks, atau penalaran non-rutin.	**Asesor 1:** Instrumen motivasi belajar telah dijelaskan dengan mencantumkan dasar model ARCS, karakteristik butir, prosedur penskoran, serta informasi pengujian kualitas instrumen dan reliabilitasnya. **Asesor 2:** Alasan pemilihan Teorema Pythagoras telah diperjelas berdasarkan karakteristik tugas yang menuntut pemahaman representasi, pemilihan strategi, penalaran, dan penyelesaian masalah matematika.
R1-10. Identifikasi instrumen asli/adaptasi self-efficacy dan jelaskan proses adaptasi, jumlah item per dimensi, skala respons, penskoran, serta adaptasi bahasa/budaya.	R2-10. Hindari klaim “novelty” berlebihan; gunakan “specific contribution” dalam konteks pemecahan masalah Pythagoras.	**Asesor 1:** Instrumen mathematical self-efficacy telah dijelaskan berdasarkan dimensi level, strength, dan generality, termasuk sumber instrumen, skala respons, prosedur penskoran, dan penyesuaian bahasa yang digunakan dalam penelitian. **Asesor 2:** Kontribusi penelitian telah dirumuskan secara proporsional sebagai kontribusi spesifik dalam konteks pemecahan masalah terkait Teorema Pythagoras, tanpa klaim kebaruan yang berlebihan.
R1-11. Laporkan jumlah soal, rentang skor, rubrik, alokasi waktu, contoh soal, penilai jawaban esai, dan reliabilitas antarpenilai.	R2-11. Sajikan pertanyaan penelitian sebagai nomor atau hipotesis eksplisit agar mudah dihubungkan dengan hasil dan kesimpulan.	**Asesor 1:** Tes berpikir kritis telah dilengkapi dengan uraian mengenai indikator Ennis, bentuk dan cakupan soal, rubrik penskoran, prosedur pelaksanaan, serta pemeriksaan kualitas instrumen. **Asesor 2:** Pertanyaan penelitian telah disajikan secara eksplisit dan bernomor (RQ.1, RQ.2, dan RQ.3) agar keterkaitannya dengan hasil dan kesimpulan mudah ditelusuri.
R1-12. Sebutkan jumlah dan kualifikasi ahli, kriteria penilaian, serta cara menghitung kesepakatan (misalnya Aiken’s V/CVI).	R2-12. Jelaskan hubungan teori Bandura antara motivasi, self-efficacy, dan berpikir kritis; model saat ini belum diturunkan secara konseptual.	**Asesor 1:** Validitas isi instrumen telah dijelaskan melalui penilaian tiga ahli bergelar doktor. Kriteria penilaian mencakup relevansi isi, representasi konstruk, kejelasan bahasa, keterbacaan, dan kesesuaian dengan karakteristik siswa; kesepakatan ahli dihitung menggunakan Aiken’s V. **Asesor 2:** Landasan teori telah diperkuat dengan menjelaskan keterkaitan motivasi belajar, mathematical self-efficacy, dan berpikir kritis berdasarkan perspektif teori Bandura.
R1-13. Laporkan hasil asumsi statistik di Results, terutama multivariate normality dan multicollinearity.	R2-13. Jelaskan apakah item self-efficacy merujuk khusus pada tugas Pythagoras atau matematika secara umum.	**Asesor 1:** Asumsi statistik telah dijelaskan pada bagian analisis, termasuk pemeriksaan normalitas multivariat serta multikolinearitas menggunakan nilai tolerance dan VIF. **Asesor 2:** Referen butir mathematical self-efficacy telah diperjelas sehingga pembaca mengetahui apakah penilaian kemampuan siswa merujuk pada tugas matematika secara umum atau konteks penyelesaian masalah yang diteliti.
R1-14. Hitung dan laporkan CR serta AVE secara terpisah untuk learning motivation, mathematical self-efficacy, dan critical thinking; jangan hanya satu nilai gabungan 12 indikator.	R2-14. Laporkan durasi tes dan apakah guru, instruksi, serta kondisi pengujian sama bagi semua siswa.	**Asesor 1:** Reliabilitas komposit (CR) dan average variance extracted (AVE) telah disajikan secara terpisah untuk konstruk learning motivation, mathematical self-efficacy, dan critical thinking sehingga kualitas pengukuran setiap konstruk dapat dinilai. **Asesor 2:** Prosedur pelaksanaan tes telah diperjelas, termasuk pengawasan guru, instruksi, alokasi waktu, dan upaya menjaga kondisi pengujian yang setara bagi seluruh peserta.
R1-15. Sebutkan estimator SEM (misalnya maximum likelihood/robust ML) serta penanganan data Likert ordinal, missing values, dan non-normality.	R2-15. Perbaiki huruf awal yang hilang menjadi “The” dan lakukan proofreading untuk spasi, simbol, hyphenation, dan kata terpotong.	**Asesor 1:** Metode estimasi SEM dan penanganan karakteristik data telah dijelaskan, termasuk pertimbangan skala respons, data hilang, dan distribusi data dalam proses analisis. **Asesor 2:** Naskah telah menjalani proofreading untuk memperbaiki huruf awal yang hilang, tata bahasa, spasi, simbol, pemenggalan kata, dan konsistensi istilah.
R1-16. Laporkan nilai R^2 untuk critical thinking dan bahas kaitannya dengan pertanyaan penelitian ketiga.	R2-16. Tidak ada mean, SD, distribusi, atau rentang skor di bawah heading; tambahkan statistik deskriptif atau ubah heading menjadi “Preliminary Measurement Analysis”.	**Asesor 1:** Nilai R^2 untuk konstruk critical thinking telah dicantumkan dan diinterpretasikan untuk menjelaskan proporsi varians yang dapat diterangkan oleh prediktor dalam model. **Asesor 2:** Bagian hasil telah ditata dengan heading yang sesuai dan dilengkapi statistik deskriptif, meliputi mean, standard deviation, distribusi, dan rentang skor.
R1-17. Subbagian Descriptive Statistics tidak berisi statistik deskriptif; tambahkan mean, SD, rentang, skewness, korelasi, atau ubah nama	R2-17. Uraian KMO/Bartlett berulang; ringkas dan beri ruang lebih banyak pada korelasi, koefisien jalur, dan explained variance.	**Asesor 1:** Bagian hasil telah ditata ulang agar menyajikan statistik deskriptif yang relevan, termasuk ukuran pemusatan, penyebaran, rentang, dan

Revisi Asesor 1	Revisi Asesor 2	Hasil Revisi
subbagian.		informasi distribusi data sebelum pembahasan hasil CFA/SEM. **Asesor 2:** Uraian KMO dan Bartlett telah diringkas agar tidak berulang. Penyajian hasil lebih diarahkan pada korelasi, koefisien jalur, dan varians yang dijelaskan oleh model.
R1-18. KMO dan Bartlett hanya menunjukkan kelayakan matriks korelasi untuk analisis faktor, bukan membuktikan kecukupan model pengukuran konfirmatori; lunakkan klaim dan gunakan bukti CFA, loading, reliabilitas, validitas.	R2-18. Terjemahkan caption gambar sepenuhnya ke bahasa Inggris dan jelaskan isi gambar, misalnya “Figure 2. Initial confirmatory factor analysis model.”	**Asesor 1:** Interpretasi KMO dan Bartlett telah dibatasi sebagai pemeriksaan awal kelayakan matriks korelasi. Kecukupan model pengukuran selanjutnya dijelaskan berdasarkan hasil CFA, factor loading, reliabilitas, dan validitas konstruk. **Asesor 2:** Caption gambar telah diterjemahkan dan diseragamkan dalam bahasa Inggris, serta dilengkapi keterangan yang menjelaskan isi dan fungsi setiap gambar.
R1-19. Jelaskan model pada Figure 2 yang tampak menggabungkan semua indikator dalam satu faktor “Validitas”, padahal ada tiga konstruk; jelaskan poor initial fit (RMSEA=0.249).	R2-19. Seragamkan koma desimal dan titik desimal; jurnal berbahasa Inggris biasanya memakai titik di seluruh teks, tabel, dan gambar.	**Asesor 1:** Model pengukuran pada Figure 2 telah diperjelas dengan membedakan tiga konstruk penelitian. Model awal dan nilai RMSEA awal dijelaskan sebagai dasar evaluasi serta perbaikan model pengukuran. **Asesor 2:** Format angka desimal telah diseragamkan menggunakan titik desimal pada teks, tabel, dan gambar sesuai konvensi penulisan artikel berbahasa Inggris.
R1-20. Petakan X1–X12 ke konstruk dan dimensi masing-masing serta gunakan bahasa Inggris pada caption dan heading.	R2-20. Gambar sulit dibaca; ekspor ulang dengan resolusi tinggi, label Inggris konsisten, koefisien terbaca, dan pangkas latar kosong.	**Asesor 1:** Indikator X1–X12 telah dipetakan secara jelas ke konstruk dan dimensi masing-masing. Caption, label, dan heading gambar telah diseragamkan menggunakan bahasa Inggris. **Asesor 2:** Figure 2–4 telah ditata ulang dengan resolusi yang memadai, label berbahasa Inggris yang konsisten, koefisien yang terbaca, dan komposisi gambar yang lebih ringkas.
R1-21. Rumus dan perhitungan antara hilang; masukkan persamaan dengan benar atau hapus fragmen dan tampilkan hasil akhir per konstruk dalam tabel.	R2-21. Terjemahkan heading tabel ke bahasa Inggris; sederhanakan menjadi Index, Recommended criterion, Obtained value, Interpretation.	**Asesor 1:** Persamaan dan perhitungan yang diperlukan telah ditata kembali agar terbaca. Hasil akhir pengujian reliabilitas dan validitas ditampilkan dalam tabel terstruktur untuk setiap konstruk. **Asesor 2:** Heading dan label tabel telah diterjemahkan serta disederhanakan menggunakan istilah bahasa Inggris yang konsisten, seperti Index, Recommended Criterion, Obtained Value, dan Interpretation.
R1-22. Jelaskan konstruk yang diwakili nilai CR; satu nilai reliabilitas gabungan tiga variabel laten tidak membuktikan reliabilitas masing-masing konstruk.	R2-22. Ganti “Cut of Value” menjadi “Cut-off Value” atau “Recommended Criterion” dan isi ambang batas yang kosong.	**Asesor 1:** Nilai CR telah dijelaskan berdasarkan konstruk yang diwakilinya dan dilaporkan secara terpisah, sehingga reliabilitas masing-masing variabel laten dapat dievaluasi. **Asesor 2:** Penulisan “Cut of Value” telah diperbaiki menjadi “Cut-off Value” atau “Recommended Criterion”, dan kriteria pembanding yang diperlukan telah dilengkapi.
R1-23. Sebutkan parameter yang dimodifikasi, residual yang dikorelasikan, modification indices, dan alasan teoretis setiap perubahan model.	R2-23. “Are determined” terlalu kausal; gunakan “are associated with”/“may be related to” dan tinjau klaim penguasaan konsep matematika yang tidak diukur.	**Asesor 1:** Modifikasi model telah dijelaskan dengan menyebutkan korelasi residual yang relevan, dasar modification indices, serta alasan teoretis berdasarkan kemiripan redaksi atau isi indikator dalam konstruk yang sama. **Asesor 2:** Ungkapan yang berpotensi menyiratkan kausalitas telah diganti dengan istilah yang menunjukkan hubungan atau asosiasi. Klaim mengenai penguasaan konsep yang tidak diukur juga telah disesuaikan.
R1-24. RMSEA=0.093 menunjukkan fit marginal/acceptable, bukan clearly good; jelaskan bahwa indeks incremental baik sementara RMSEA marginal.	R2-24. Loading tinggi menunjukkan hubungan indikator dengan konstruk, bukan bahwa siswa memiliki tingkat attention/satisfaction lebih tinggi; batasi interpretasi pada level pengukuran.	**Asesor 1:** Nilai RMSEA sebesar 0.093 telah diinterpretasikan sebagai marginal/acceptable fit, sementara indeks incremental yang memenuhi kriteria dijelaskan secara terpisah. **Asesor 2:** Interpretasi factor loading telah dibatasi pada hubungan indikator dengan konstruk laten. Loading tidak lagi digunakan sebagai bukti langsung bahwa siswa memiliki tingkat attention atau satisfaction yang lebih tinggi.
R1-25. Table 3 salah mengklasifikasikan RMSEA=0.150 sebagai Good; perbaiki menjadi buruk dan isi kolom Cut-off Value.	R2-25. Terjemahkan heading berbahasa Indonesia menjadi “Structure of the Mathematical Self-Efficacy Construct” dan periksa istilah lain yang belum diterjemahkan.	**Asesor 1:** Klasifikasi RMSEA sebesar 0.150 pada tabel telah diperbaiki menjadi “Not Good”, dan nilai kriteria pembanding telah dilengkapi. **Asesor 2:** Heading berbahasa Indonesia telah diterjemahkan menjadi “Structure of the Mathematical Self-Efficacy Construct”, dan istilah lain pada tabel serta gambar telah diseragamkan dalam bahasa Inggris.
R1-26. Signifikansi statistik tidak otomatis berarti hipotesis didukung; koefisien motivasi negatif tidak mendukung hipotesis positif. Bedakan	R2-26. Jangan menafsirkan loading tertinggi sebagai bukti persistence	**Asesor 1:** Interpretasi hasil telah membedakan signifikansi statistik dari dukungan terhadap hipotesis berdasarkan arah hubungan. Hubungan negatif

Revisi Asesor 1	Revisi Asesor 2	Hasil Revisi
signifikan dan didukung sesuai arah hipotesis.	merupakan mekanisme psikologis terpenting jika mekanisme itu tidak diuji.	learning motivation dijelaskan sebagai hasil yang tidak mendukung hipotesis positif, tanpa menyimpulkan bahwa motivasi merugikan siswa. **Asesor 2:** Interpretasi loading tertinggi telah dibatasi pada kontribusi indikator terhadap konstruk. Persistence tidak dinyatakan sebagai mekanisme psikologis yang terbukti apabila mekanisme tersebut tidak diuji secara langsung.
R1-27. Sajikan koefisien terstandar/tidak terstandar, standard error, t, p eksak, dan confidence interval untuk setiap jalur.	R2-27. Loading tidak membuktikan transfer lintas konteks; hanya menunjukkan hubungan indikator generality dengan konstruk laten.	**Asesor 1:** Pelaporan jalur struktural telah dilengkapi dengan koefisien yang relevan, standard error, nilai t, nilai p, dan interval kepercayaan agar kekuatan serta ketepatan estimasi dapat dievaluasi. **Asesor 2:** Interpretasi dimensi generality telah dibatasi pada hubungan indikator dengan konstruk mathematical self-efficacy dan tidak diperlakukan sebagai bukti transfer kemampuan lintas konteks.
R1-28. Cocokkan kalimat dengan koefisien pada Figure 4 karena nilai jalur negatif pada gambar tampak berbeda dari −0.69; samakan semua angka.	R2-28. Jelaskan relevansi konseptual studi dari pendidikan sains/Pancasila dan prioritaskan studi matematika yang sebanding.	**Asesor 1:** Koefisien jalur pada narasi, tabel, dan Figure 4 telah diselaraskan sehingga nilai dan arah hubungan yang dilaporkan konsisten di seluruh naskah. **Asesor 2:** Referensi dari bidang pendidikan lain telah diberi konteks relevansi teoretis, sementara pembahasan diprioritaskan pada penelitian matematika yang sebanding dengan fokus studi.
R1-29. Lengkapi diagnostik: korelasi prediktor, VIF/diagnostik setara, standard error, dan ada/tidaknya negative error variance atau improper estimate.	R2-29. Loading rendah bukan berarti proficiency siswa rendah; proficiency harus didasarkan pada mean, distribusi skor, atau performa item.	**Asesor 1:** Diagnostik model telah dilengkapi dengan pemeriksaan hubungan antar-prediktor, tolerance, VIF, standard error, serta evaluasi kemungkinan negative error variance dan improper estimates. **Asesor 2:** Interpretasi loading rendah telah dibatasi pada kualitas hubungan indikator dengan konstruk dan tidak digunakan untuk menyimpulkan rendahnya proficiency siswa.
R1-30. Lunakkan kesimpulan sampai CR/AVE dilaporkan per konstruk dan struktur pengukuran tiga faktor diperjelas; pertimbangkan keterbatasan sampel dan modifikasi model.	R2-30. Kalimat merujuk pada model/studi sebelumnya tanpa identitas jelas; sebutkan dan sitasi studi atau nyatakan sebagai interpretasi teoretis penulis.	**Asesor 1:** Kesimpulan telah disusun dengan mempertimbangkan sifat eksploratif sampel, hasil evaluasi model, dan proses modifikasi. Klaim mengenai peran mathematical self-efficacy disampaikan sebagai asosiasi dalam model yang diestimasi, bukan sebagai hubungan kausal. **Asesor 2:** Rujukan terhadap model atau penelitian terdahulu telah diperjelas dengan identitas sumber dan sitasi yang sesuai; pernyataan yang merupakan interpretasi penulis dibedakan dari temuan penelitian terdahulu.
—	R2-31. Mediasi tidak diuji; nyatakan sebagai kemungkinan teoretis dari penelitian terdahulu, bukan temuan empiris studi ini.	**Asesor 2:** Pembahasan telah menegaskan bahwa mediasi tidak diuji dalam penelitian ini. Mediasi hanya disampaikan sebagai kemungkinan teoretis berdasarkan literatur, bukan sebagai temuan empiris penelitian.
—	R2-32. Suppression effect masuk akal tetapi harus didukung korelasi bivariat, korelasi prediktor, dan diagnostik; tanpa data itu nyatakan sebagai kemungkinan tentatif.	**Asesor 2:** Suppression effect telah dijelaskan sebagai kemungkinan interpretasi yang bersifat tentatif dan dikaitkan dengan hubungan antar-prediktor serta kemungkinan overlap konstruk.
—	R2-33. Hubungkan strategi pembelajaran dengan empat sumber self-efficacy Bandura: mastery experiences, vicarious experiences, verbal persuasion, dan emotional states.	**Asesor 2:** Implikasi pembelajaran telah dihubungkan dengan empat sumber self-efficacy Bandura: mastery experiences, vicarious experiences, verbal persuasion, dan emotional states.
—	R2-34. Kurangi pengulangan pesan di Discussion, Implications, Suggestions, dan Conclusion; gunakan ruang untuk boundary conditions dan koefisien motivasi negatif.	**Asesor 2:** Pengulangan antara Discussion, Implications, Suggestions, dan Conclusion telah dikurangi. Pembahasan difokuskan pada batas interpretasi, koefisien negatif motivasi, dan implikasi hasil.
—	R2-35. Tambahkan keterbatasan self-report, shared-method variance, overlap ARCS confidence dengan self-efficacy, dan modifikasi model berbasis data.	**Asesor 2:** Bagian keterbatasan telah diperluas dengan mencakup penggunaan self-report, potensi shared-method variance, kemungkinan overlap antara confidence pada model ARCS dan self-efficacy, serta modifikasi model berbasis data.
—	R2-36. Ganti frasa “causal development” yang janggal dengan “examine temporal ordering and provide stronger evidence regarding causal relationships.”	**Asesor 2:** Frasa “causal development” telah diganti dengan “examine temporal ordering and provide stronger evidence regarding causal relationships” agar lebih tepat secara metodologis dan gramatikal.
—	R2-37. Jelaskan bahwa koefisien motivasi negatif bersyarat pada masuknya self-efficacy dan mungkin dipengaruhi overlap prediktor; jangan membuat kesan motivasi berbahaya.	**Asesor 2:** Koefisien negatif learning motivation telah dijelaskan sebagai hubungan bersyarat ketika mathematical self-efficacy dimasukkan dalam model, dengan mempertimbangkan kemungkinan overlap antar-prediktor; hasil tersebut tidak ditafsirkan sebagai bukti bahwa motivasi merugikan.

Revisi Asesor 1	Revisi Asesor 2	Hasil Revisi
—	R2-38. Lunakkan “should prioritize” karena studi observasional dengan satu sampel kecil; gunakan “suggest that educators may consider strengthening…”.	**Asesor 2:** Rekomendasi praktis telah dilunakkan menjadi “suggest that educators may consider strengthening…” agar sejalan dengan desain observasional dan ukuran sampel penelitian.
—	R2-39. Format ulang nama penulis sesuai gaya jurnal (nama keluarga dan inisial); judul artikel gunakan sentence case.	**Asesor 2:** Daftar pustaka telah diformat ulang sesuai gaya jurnal, termasuk penulisan nama penulis menggunakan nama keluarga dan inisial serta penggunaan sentence case pada judul artikel.
—	R2-40. Tambahkan titik dua atau titik antara “achievement” dan “A multilevel analysis”; perbaiki judul berdasarkan publikasi asli.	**Asesor 2:** Referensi Pitsia et al. telah diperbaiki dengan menambahkan tanda baca pemisah antara kata “achievement” dan “A multilevel analysis”, serta menyesuaikan judul dengan publikasi aslinya.
—	R2-41. Bedakan “Yulianto” dan “Yuliyanto” secara cermat di seluruh sitasi karena merupakan nama penulis berbeda.	**Asesor 2:** Nama penulis “Yulianto” dan “Yuliyanto” telah dibedakan secara konsisten pada daftar pustaka dan sitasi dalam teks sesuai identitas masing-masing sumber.
—	R2-42. Referensi Yulianto 2024a dan 2024b duplikat dengan judul, jurnal, halaman, dan DOI sama; hapus salah satu dan perbarui sitasi.	**Asesor 2:** Referensi Yulianto tahun 2024 yang terduplikasi telah disederhanakan dengan mempertahankan satu entri yang benar dan menyesuaikan sitasi dalam teks.

BUKTI KORESPONDENSI
ARTIKEL JURNAL TERAKREDITASI NASIONAL
SINTA 2

Judul artikel : **Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critical thinking skills: Evidence from structural equation modeling**

Jurnal : Journal of Advanced Sciences and Mathematics Education, Vol. 6, No 3. hal 326 -351, Agustus 2026

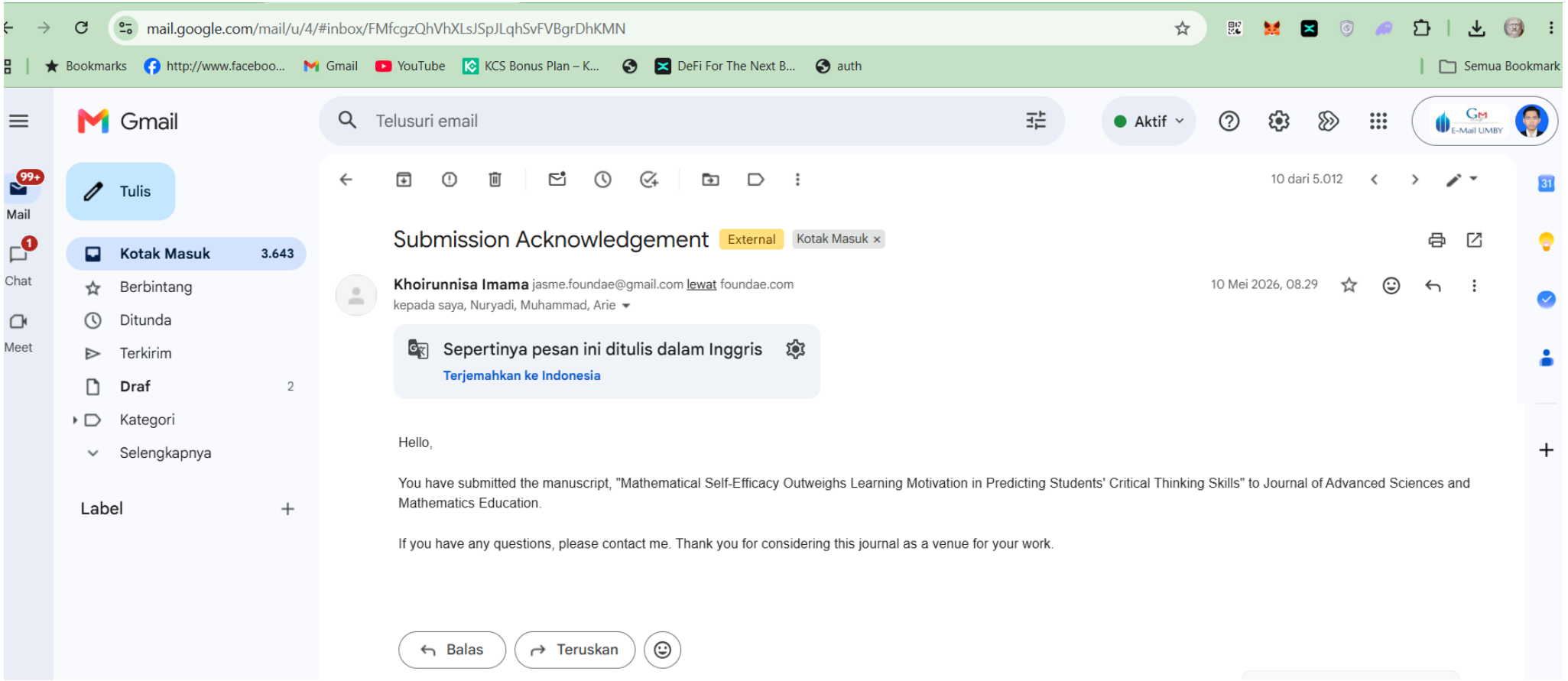
Doi : 10.58524/jasme.v6i3.1480

Penulis : Nanang Khuzaini, Nuryadi, M. Irfan Rumasoreng, M. Farid Nasrulloh, Arie Purwanto

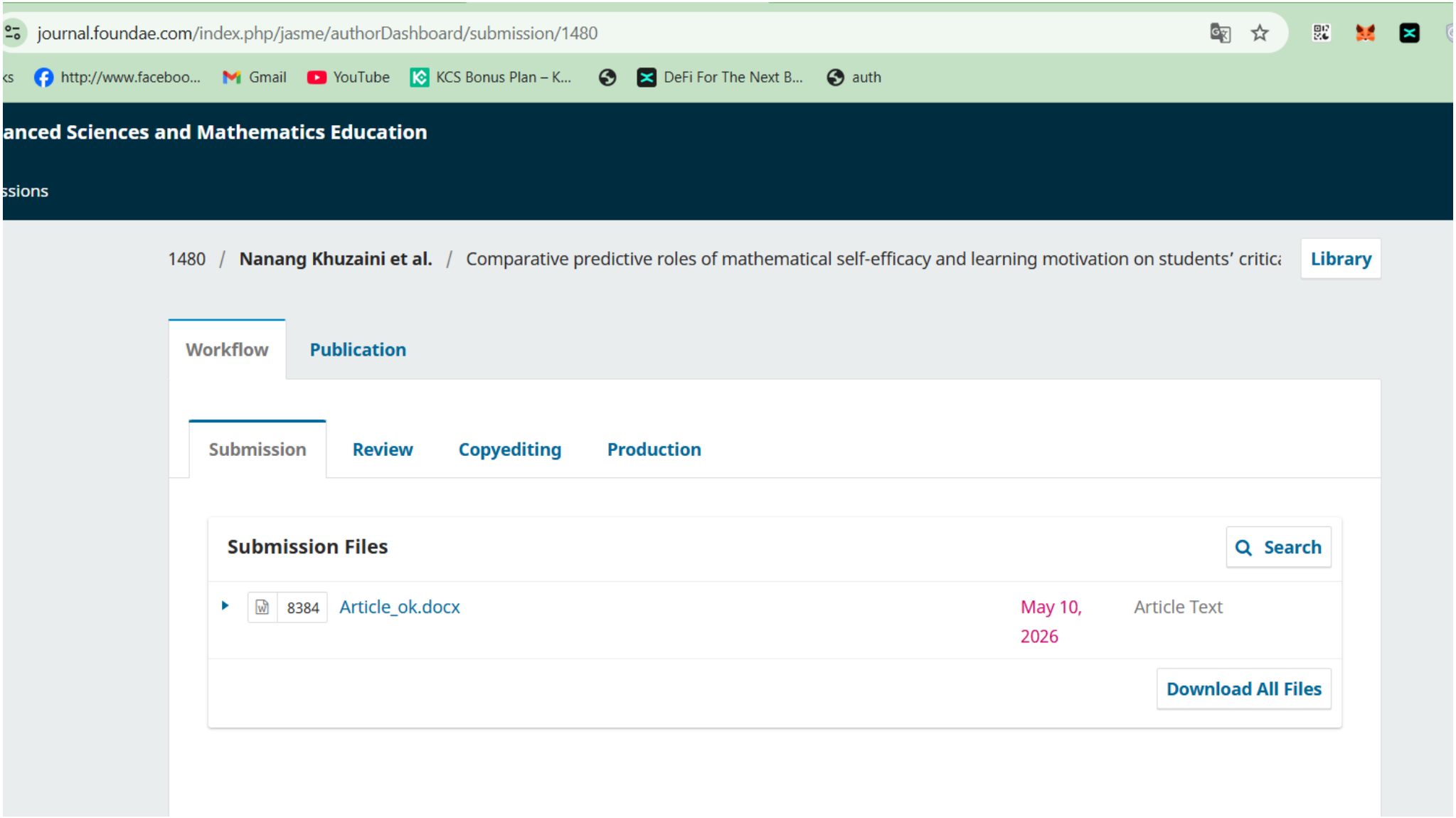
No	Perihal	Tanggal
1	Bukti konfirmasi submit artikel dan artikel yang disubmit	10 Mei 2026
2	Jurnal di kirim kepada reviewer untuk di review (2 reviewer)	25 Mei 2026
3	Keputusan Editor (Revisions Required) _ 1 (2 reviewer)	1 juni 2026
4	Bukti konfirmasi submit revisi, respon kepada reviewer dan artikel yang diresubmit	25 Juni 2026
5	Bukti konfirmasi artikel accepted	1 Agustus 2026
6	Bukti konfirmasi artikel masuk tahap produksi	1 Agustus 2026
7	Artikel Publis online	2 Agustus 2026

1. Bukti konfirmasi submit artikel dan artikel yang disubmit 10 Mei 2026

a. Via Email

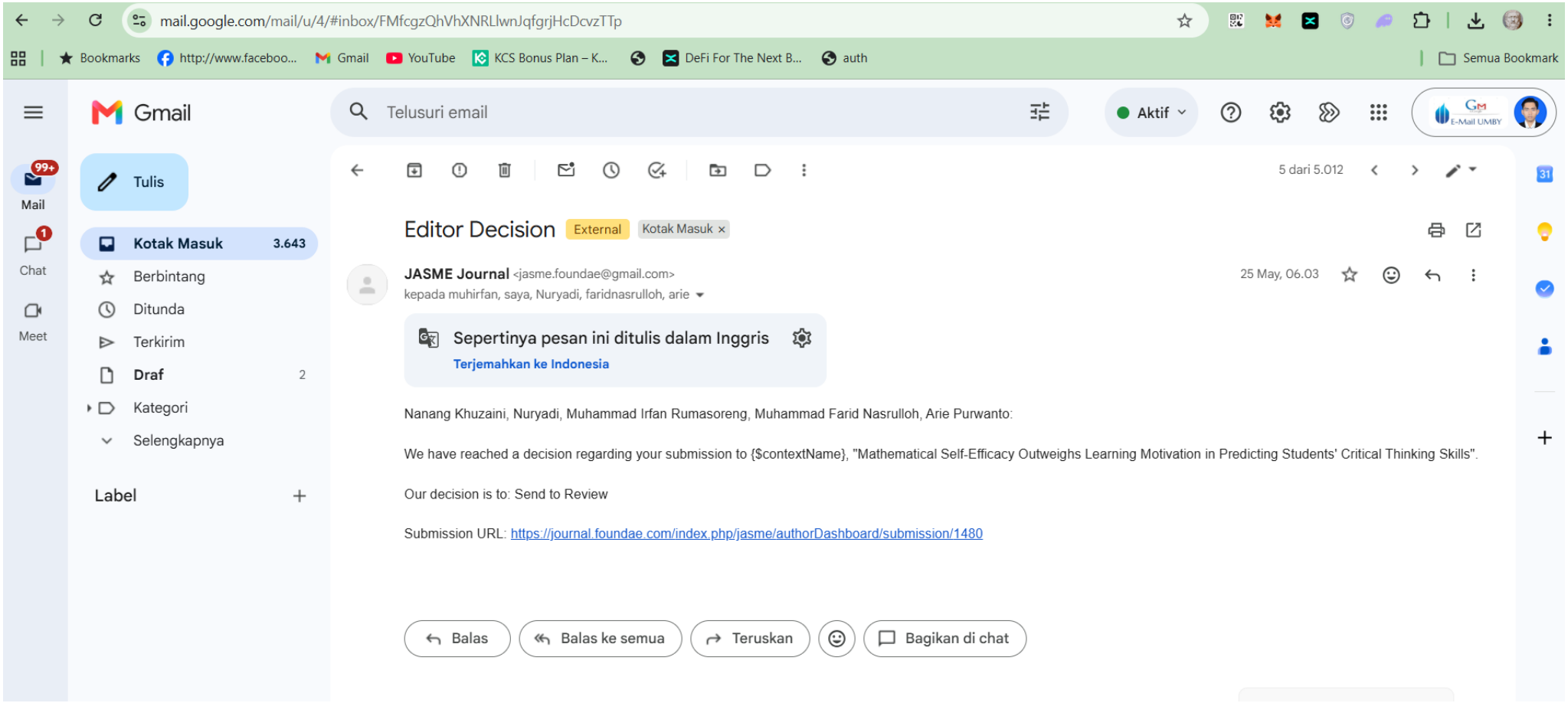


b. Via OJS

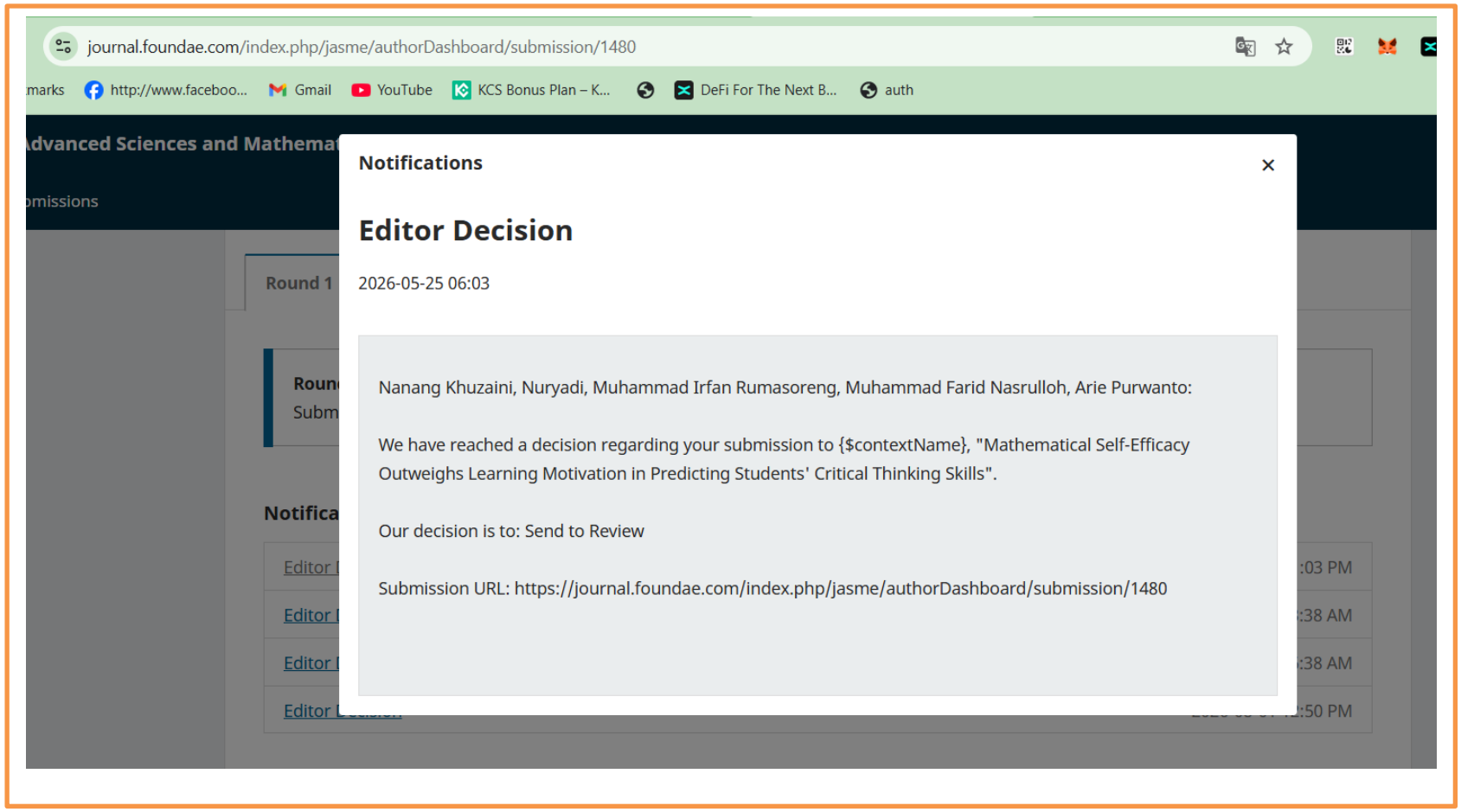

journal.foundae.com/index.php/jasme/authorDashboard/submission/1480
http://www.faceboo...
Gmail
YouTube
KCS Bonus Plan – K...
DeFi For The Next B...
auth
anced Sciences and Mathematics Education
ssions
1480 / Nanang Khuzaini et al. / Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critic
Library
Workflow
Publication
Submission
Review
Copyediting
Production
Submission Files
Search
8384
Article_ok.docx
May 10, 2026
Article Text
Download All Files

2. Jurnal di kirim kepada reviewer untuk di review , 25 Mei 2026

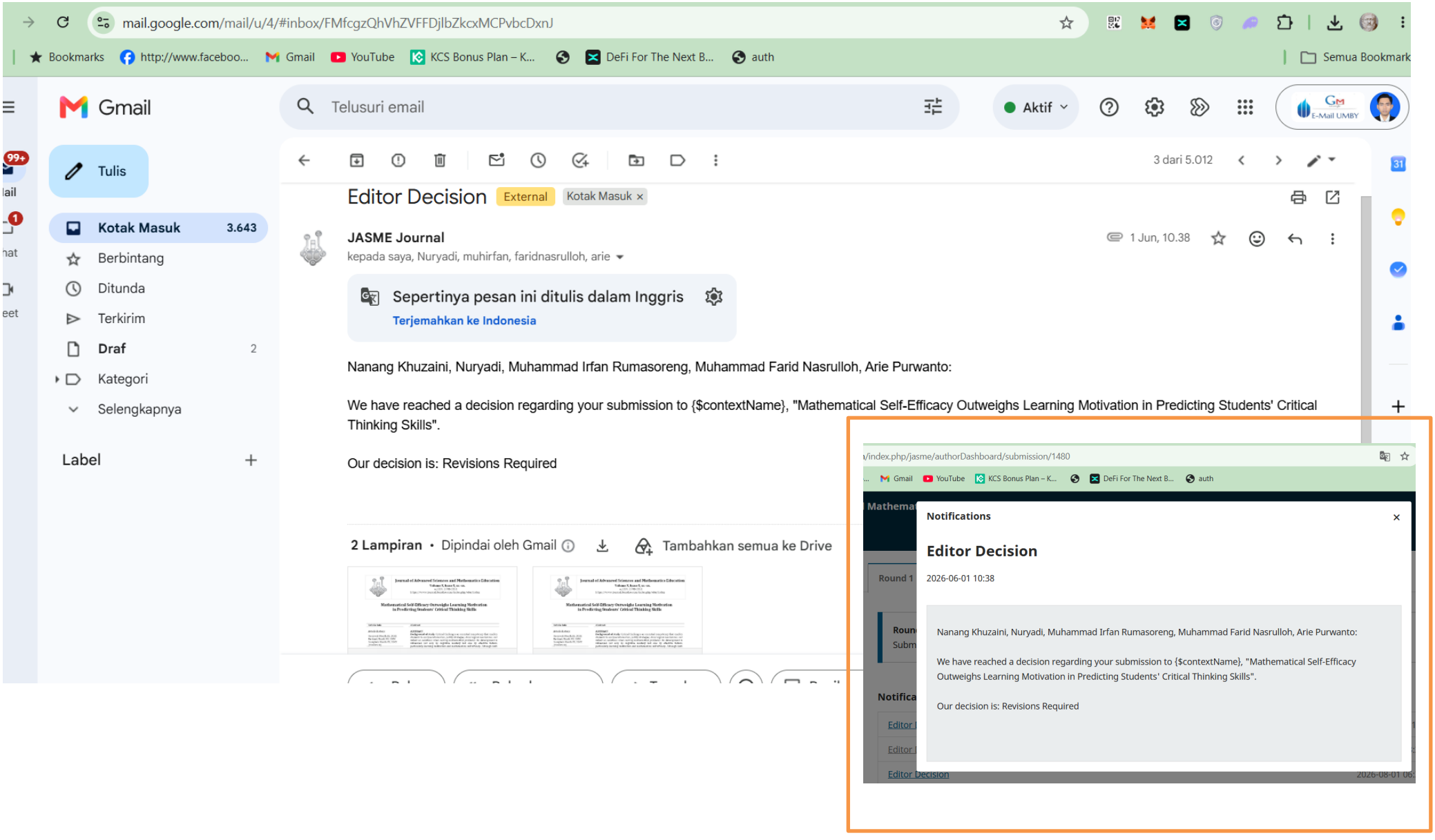
a. Via email



b. Via OJS


journal.foundae.com/index.php/jasme/authorDashboard/submission/1480
marks
http://www.faceboo...
Gmail
YouTube
KCS Bonus Plan – K...
DeFi For The Next B...
auth
Notifications
Editor Decision
2026-05-25 06:03
Nanang Khuzaini, Nuryadi, Muhammad Irfan Rumasoreng, Muhammad Farid Nasrulloh, Arie Purwanto:
We have reached a decision regarding your submission to {$contextName}, "Mathematical Self-Efficacy Outweighs Learning Motivation in Predicting Students' Critical Thinking Skills".
Our decision is to: Send to Review
Submission URL: https://journal.foundae.com/index.php/jasme/authorDashboard/submission/1480
Round 1

3. **Keputusan Editor (Revision Required) (2 reviewer), 1 Juni 2026 (revisi lengkap ada pada lampiran)**



contoh komentar dan revisi dari reviewer, detail ada pada lampiran

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participants

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected through simple random sampling to ensure that every student had an equal probability of participation.

Prior to data collection, students and the school administration were informed abo
of the study, and participation was voluntary. All collected data were treated confi
used solely for research purposes.

Instruments

Three research instruments were employed.

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire dev
Keller's ARCS motivational model, consisting of four dimensions: Attention, Releva
and Satisfaction. Responses were recorded on a five-point Likert scale ranging fror
disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandu
framework. The instrument measured three dimensions:

a. Level
b. Strength
c. Generality

The questionnaire evaluated students' confidence in completing mathemati

Commented [6]: Please explain how the random selection was

Journal of Advanced Sciences and Mathematics Education
Volume X, Issue X, xx -xx.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index

Mathematical Self-Efficacy Outweighs Learning Motivation in Predicting Students' Critical Thinking Skills

Commented [1]: The title is memorable, but it sounds more conclusive than the study design allows. Because the analysis is cross-sectional and context-specific, please consider a title that emphasises comparison rather than superiority.

Article Info

Article history:

Received: Month XX, 20XX
Revised: Month XX, 20XX
Accepted: Month XX, 20XX
(Cambria 9)

Keywords:

Critical Thinking Skills
Motivation to Learn
Maths Self-Efficacy

Abstract

ABSTRACT

Background of study: Critical thinking is an essential competency that enables students to analyse information, justify strategies, draw logical conclusions, and reflect on solutions when solving mathematical problems. Its development is influenced not only by cognitive mastery but also by affective factors, particularly learning motivation and mathematical self-efficacy. Although both constructs are frequently associated with mathematical performance, their relative contributions to students' critical thinking remain insufficiently explained.

Aims and scope of paper: This study aims to examine the structural relationships between learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving mathematical problems related to the Pythagorean theorem. It also compares the relative effects of learning motivation and mathematical self-efficacy on critical thinking.

Methods: A quantitative cross-sectional correlational design was employed. The population comprised 76 eighth-grade students at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Indonesia. A total of 34 students, consisting of 17 males and 17 females, were selected through simple random sampling. Data were collected using a learning motivation questionnaire based on the ARCS model, a mathematical self-efficacy questionnaire covering level, strength, and generality, and a critical thinking test based on Ennis' indicators. The data were analysed using Confirmatory Factor Analysis and Structural Equation Modeling with LISREL 8.80.

Result: The KMO value of 0.892 and a significant Bartlett's Test confirmed the suitability of the data for factor analysis. All indicators had factor loadings above 0.50 and significantly represented their respective constructs. Following model reanalysis, the structural model achieved acceptable fit, with NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, and RMSEA = 0.093. Mathematical self-efficacy had a positive and significant effect on critical thinking (t = 4.40), whereas learning motivation showed a significant negative relationship (t = −2.26).

Conclusion: Mathematical self-efficacy plays a more proximal and dominant role

Commented [2]: The manuscript mixes British and American English. Please select one variety and use it consistently. If British English is retained, consider "analysed" and "modelling"; if American English is retained, use "analyze" and "memorized."

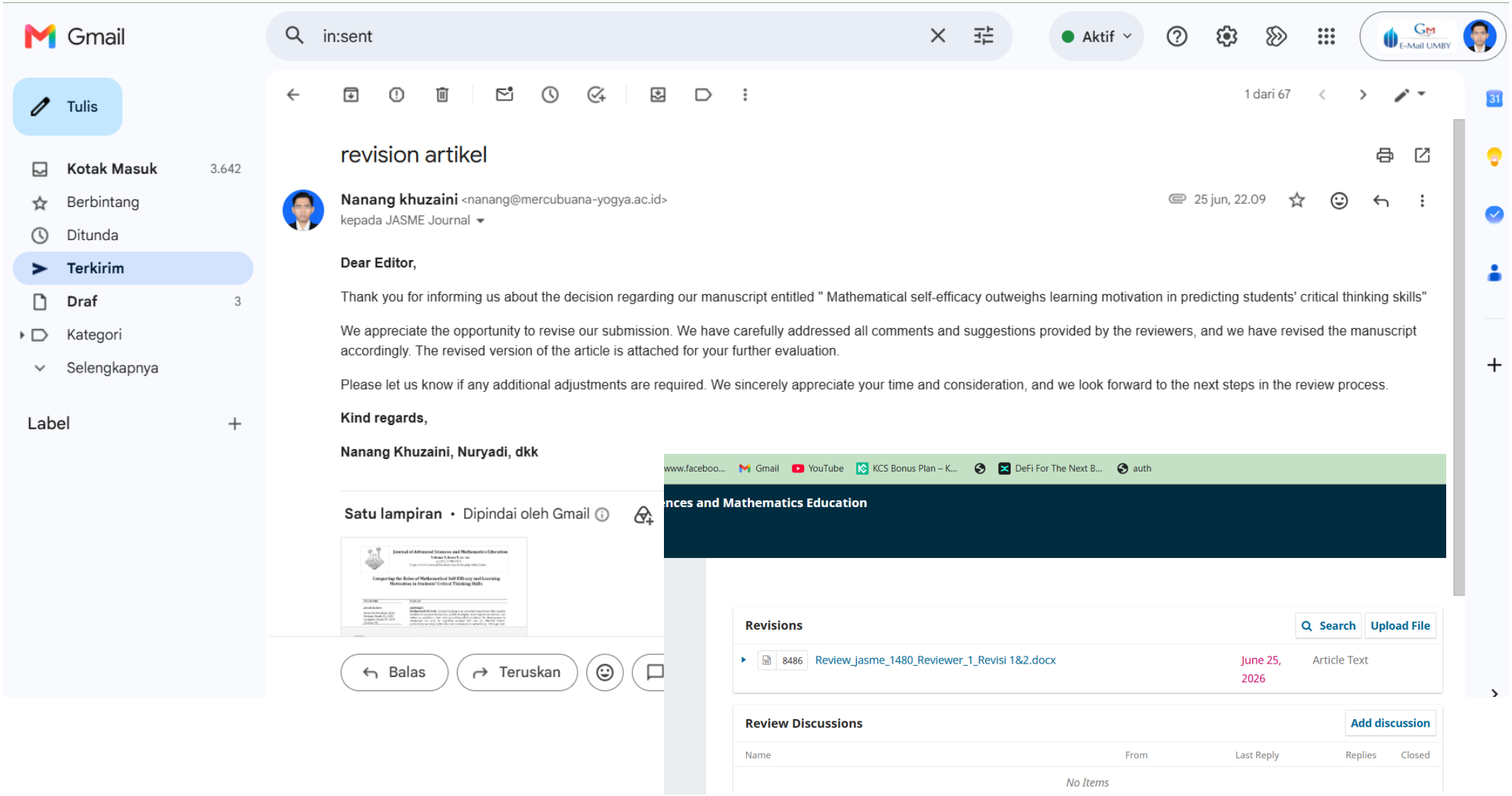
Commented [3]: "Aims and scope of paper" sounds somewhat unusual for an empirical abstract. "Purpose" or "Objective" would be more natural unless this wording is strictly required by the journal template.

Commented [5]: Please aliga the keywords with the terminology used in the title and main text. "Learning motivation" and "mathematical self-efficacy" would be more consistent than "Motivation to Learn" and "Maths Self-Efficacy."

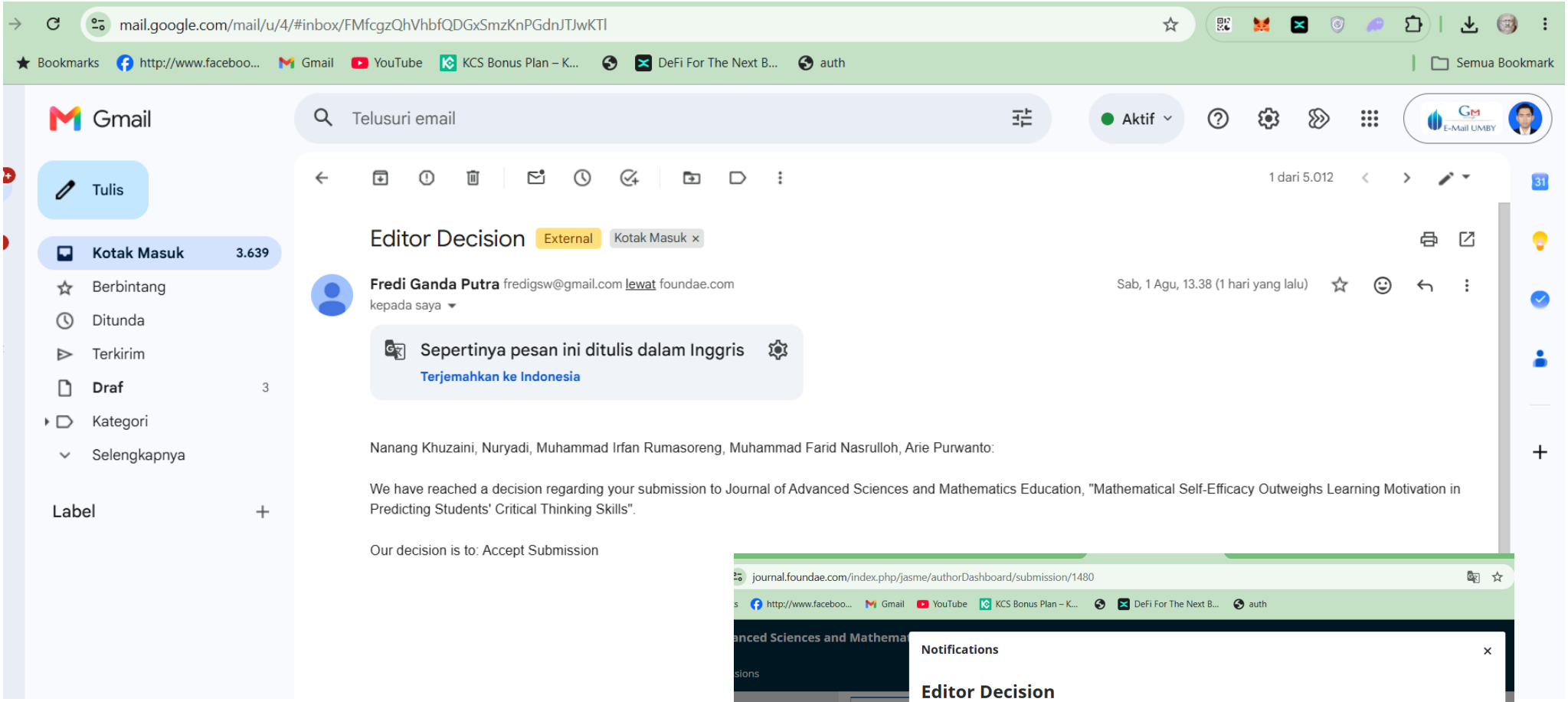
Commented [4]: Please change "Result" to "Results," as the paragraph reports several findings rather than a single result.

4. Bukti konfirmasi submit revisi, respon kepada reviewer dan artikel yang diresubmit, 25 Juni 2026

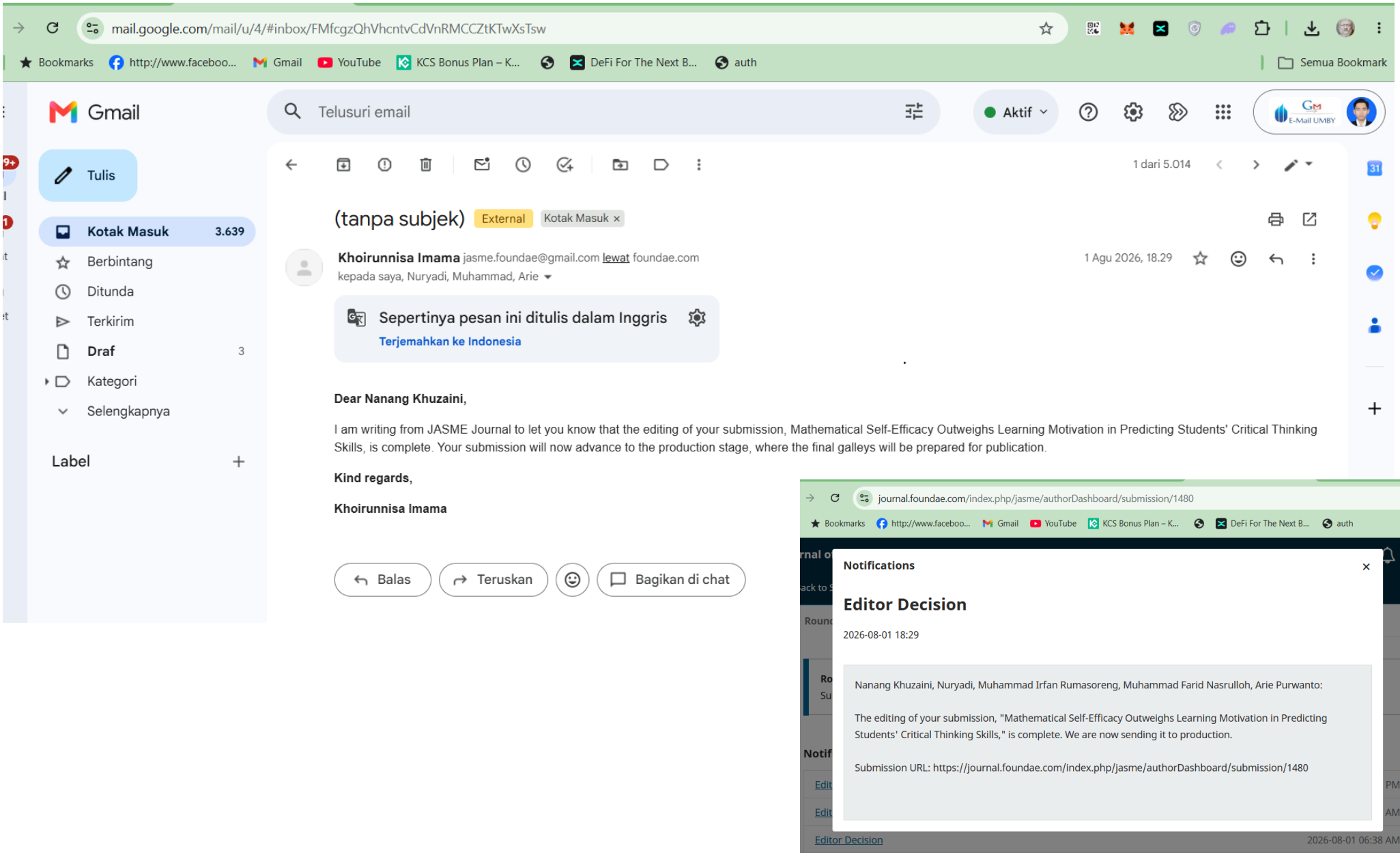
a. Via email dan via OJS



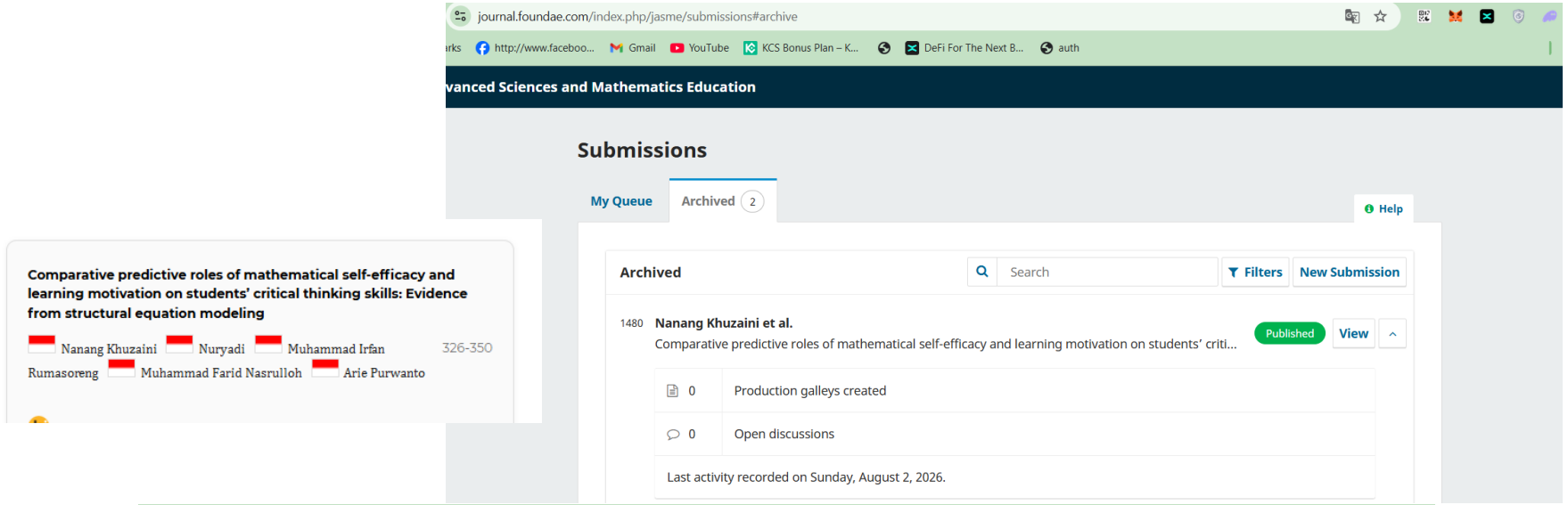
5. Bukti konfirmasi artikel accepted, 1 Agustus 2026

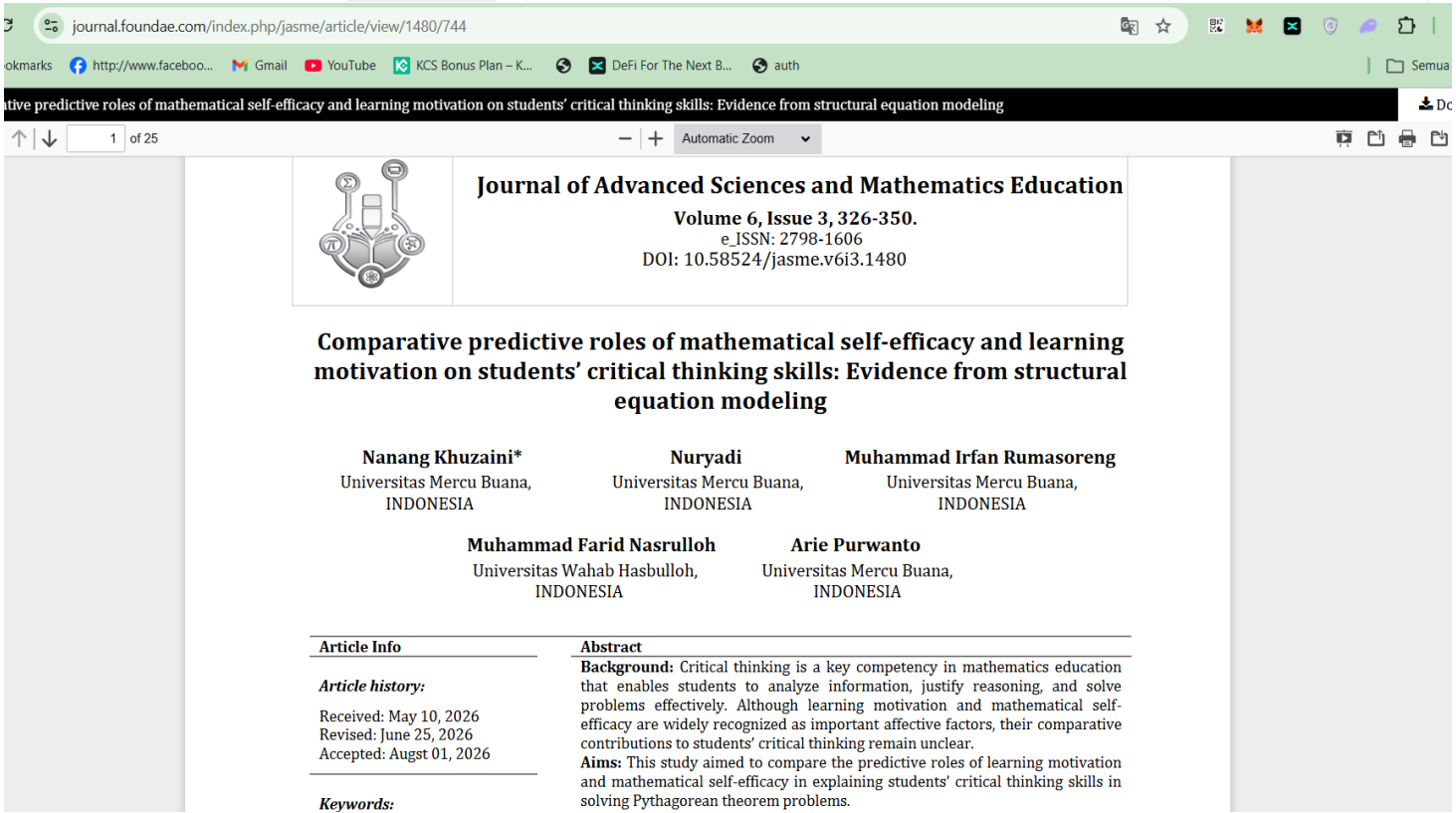


6. Bukti konfirmasi artikel masuk tahap produksi, 1 Agustus 2025



7. Artikel Publis online, 2 Agustus 2026





1. Artikel Submission

Journal of Advanced Sciences and Mathematics Education

Volume X, Issue X, xx -xx.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index

Mathematical Self-Efficacy Outweighs Learning Motivation in Predicting Students' Critical Thinking Skills

Article Info

Article history:

Received: Month XX, 20XX
Revised: Month XX, 20XX
Accepted: Month XX, 20XX
(Cambria 9)

Keywords:

Critical Thinking Skills
Motivation to Learn
Maths Self-Efficacy

Abstract

ABSTRACT

Background of study: Critical thinking is an essential competency that enables students to analyse information, justify strategies, draw logical conclusions, and reflect on solutions when solving mathematical problems. Its development is influenced not only by cognitive mastery but also by affective factors, particularly learning motivation and mathematical self-efficacy. Although both constructs are frequently associated with mathematical performance, their relative contributions to students' critical thinking remain insufficiently explained.

Aims and scope of paper: This study aims to examine the structural relationships between learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving mathematical problems related to the Pythagorean theorem. It also compares the relative effects of learning motivation and mathematical self-efficacy on critical thinking.

Methods: A quantitative cross-sectional correlational design was employed. The population comprised 76 eighth-grade students at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Indonesia. A total of 34 students, consisting of 17 males and 17 females, were selected through simple random sampling. Data were collected using a learning motivation questionnaire based on the ARCS model, a mathematical self-efficacy questionnaire covering level, strength, and generality, and a critical thinking test based on Ennis' indicators. The data were analysed using Confirmatory Factor Analysis and Structural Equation Modeling with LISREL 8.80.

Result: The KMO value of 0.892 and a significant Bartlett's Test confirmed the suitability of the data for factor analysis. All indicators had factor loadings above 0.50 and significantly represented their respective constructs. Following model reanalysis, the structural model achieved acceptable fit, with NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, and RMSEA = 0.093. Mathematical self-efficacy had a positive and significant effect on critical thinking (t = 4.40), whereas learning motivation showed a significant negative relationship (t = −2.26).

Conclusion: Mathematical self-efficacy plays a more proximal and dominant role in supporting students' critical thinking than learning motivation. Students' confidence and persistence in performing mathematical tasks appear to be more directly connected to critical reasoning than their general willingness to learn.

To cite this article: Author. (20XX). Title. *Journal of Advanced Sciences and Mathematics Education, X*(X), XX-XX

INTRODUCTION

Critical thinking has become an essential competence in mathematics education because students are expected not only to obtain correct answers but also to examine information, justify strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Aulia et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). In such situations, students must understand the problem, identify relevant information, connect mathematical concepts, compare alternative strategies, and reflect on the reasonableness of their solutions. Nevertheless, many students still experience difficulties in analysing mathematical problems, explaining the basis of their answers, and selecting appropriate problem-solving strategies. These conditions indicate that the development of critical thinking remains an important challenge in secondary mathematics education.

Students' critical thinking performance is influenced not only by cognitive knowledge but also by affective factors that shape how they approach challenging tasks. Two factors frequently associated with mathematical learning are learning motivation and mathematical self-efficacy. Learning

motivation encourages students to participate, persist, and direct their efforts towards learning goals. Motivated students are generally expected to show greater attention, perseverance, and willingness to solve difficult problems. However, empirical evidence concerning the relationship between motivation and mathematical thinking has not always been consistent. Alotaibi, for example, found that academic self-motivation showed limited or no dependence on the mathematical thinking of secondary school students (Alotaibi, 2020). This finding suggests that students' willingness to learn may not automatically translate into the ability to analyse, evaluate, and solve mathematical problems critically.

Mathematical self-efficacy refers to students' beliefs about their capacity to perform mathematical tasks successfully (Chan et al., 2022; Farah Deeba, Sana Hafeez, Shazia Noureen, 2021; Pajares & Miller, 1995; et al., 2024; Yuliyanto et al., 2021; Zakariya, 2022). Unlike general interest or willingness to learn, self-efficacy is closely related to students' judgments about whether they can organise and carry out the actions required to solve a particular problem. Students with strong self-efficacy are more likely to attempt challenging questions, maintain effort after experiencing difficulty, test alternative strategies, and interpret mistakes as part of the learning process. Conversely, students who doubt their mathematical capabilities may avoid complex tasks, rely excessively on procedural routines, or abandon problem-solving efforts prematurely. Recent research shows that mathematics self-efficacy among secondary students varies across groups and educational levels, emphasising the need for systematic support to strengthen students' confidence in learning mathematics (Paudel & Ghimire, 2024).

Previous studies have provided evidence of a positive relationship between self-efficacy and mathematical critical thinking. Yulianto et al. reported that self-efficacy contributed significantly to students' critical mathematical thinking and interacted with the instructional approach used in mathematics classrooms (Yulianto et al., 2024a). Similarly, Marlena and Nugraheni found a strong positive correlation between self-efficacy and critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). These findings indicate that students' confidence in their mathematical capabilities may serve as an important affective foundation for engaging in complex reasoning. However, much of the existing research has examined self-efficacy in relation to critical thinking as a single association, compared critical thinking across self-efficacy levels, or investigated self-efficacy within particular instructional interventions.

This leaves several important gaps. First, motivation and mathematical self-efficacy are often studied separately, even though both constructs may operate simultaneously when students confront difficult mathematical problems. Consequently, the relative contribution of each construct to critical thinking is not yet sufficiently explained. Second, correlational evidence showing that motivation or self-efficacy is associated with critical thinking does not necessarily clarify whether each variable retains a meaningful contribution when both are included in the same model. Third, existing studies commonly assume that high learning motivation naturally supports higher-order thinking, while giving less attention to the possibility that motivation may be related to critical thinking at the bivariate level but lose its explanatory power after mathematical self-efficacy is considered. Fourth, studies focusing specifically on students' critical thinking when solving Pythagorean problems remain limited, even though this topic requires students to interpret problem situations, determine relevant relationships, select strategies, and justify mathematical conclusions.

Accordingly, the novelty of this study lies in examining learning motivation and mathematical self-efficacy simultaneously and comparing their relative roles as predictors of students' critical thinking skills. Rather than merely determining whether both affective variables correlate with critical thinking, this study investigates which construct provides the stronger direct contribution when the variables are analysed within the same structural model. This comparative perspective is important because students may possess a strong desire to learn but still hesitate when they do not believe that they can complete a mathematical task successfully. Thus, the study distinguishes between students' willingness to engage in learning and their confidence in performing the cognitive actions required for critical problem solving.

This study therefore aims to analyse the direct and simultaneous effects of learning motivation and mathematical self-efficacy on students' critical thinking skills in solving mathematics problems. Specifically, it addresses three questions: whether learning motivation significantly predicts students' critical thinking skills, whether mathematical self-efficacy significantly predicts students'

critical thinking skills, and how strongly the two variables jointly explain variations in critical thinking. By clarifying their relative contributions, the findings are expected to provide a more precise basis for designing mathematics instruction that not only stimulates students' interest and persistence but also strengthens their confidence in analysing, reasoning, and solving challenging mathematical problems.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participants

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected through simple random sampling to ensure that every student had an equal probability of participation.

Prior to data collection, students and the school administration were informed about the objectives of the study, and participation was voluntary. All collected data were treated confidentially and used solely for research purposes.

Instruments

Three research instruments were employed.

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, consisting of four dimensions: Attention, Relevance, Confidence, and Satisfaction. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework. The instrument measured three dimensions:

a. Level
b. Strength
c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks with varying levels of complexity.

Critical Thinking Test

Students' critical thinking skills were measured using essay-type mathematical problems developed within the Pythagorean Theorem context. The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:

a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

All instruments underwent expert judgment by mathematics education specialists prior to implementation to establish content validity.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, several statistical assumptions were evaluated, including normality, linearity, homogeneity, and multicollinearity.

he measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50.

The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual (SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values.

Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 (α = 0.05). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

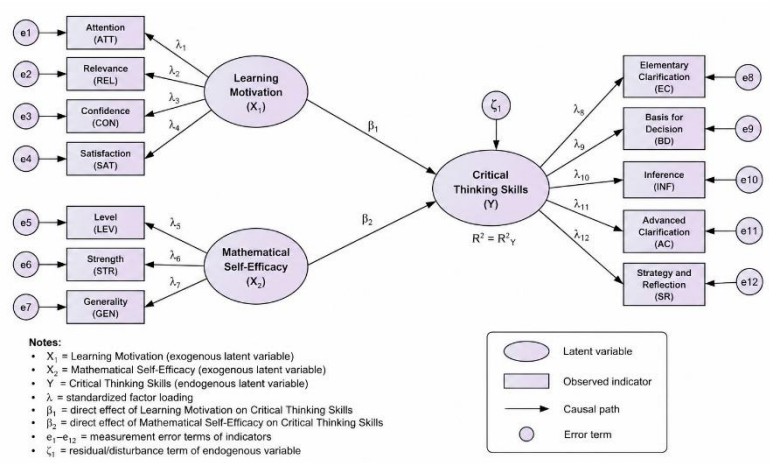


Figure 1. Proposed structural equation model of the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills.

RESULTS AND DISCUSSION

RESULTS

Preliminary Analysis

Descriptive Statistics

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were

appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis.

The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test	Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result ($\chi^2 = 1307.307$, $df = 66$, $p < 0.001$), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis.

Overall, the results of the KMO measure and Bartlett's Test provide empirical evidence that the dataset satisfies the fundamental assumptions for conducting Confirmatory Factor Analysis (CFA). Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL.

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model.

Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

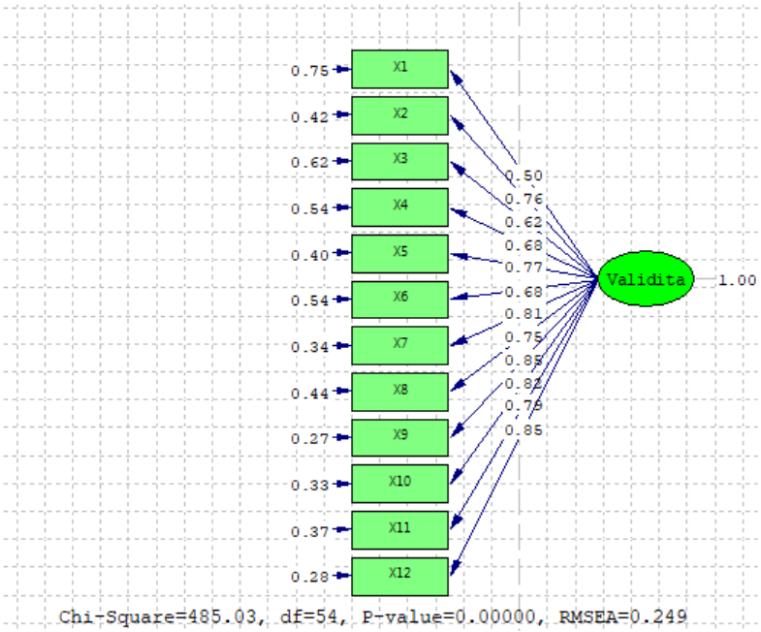


Figure 2. Uji CFA

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor dan Error Variance

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Construct Reliability (CR)
Using the Fornell & Larcker (1981) formula:

$$CR = \frac{(\sum\lambda)^2}{(\sum\lambda)^2 + \sum\varepsilon}$$

Calculation results:

$$\sum\lambda = 8{,}58$$
$$(\sum\lambda)^2 = 73{,}62$$
$$\sum\varepsilon = 5{,}30$$

so that

$$CR = \frac{73{,}62}{73{,}62 + 5{,}30} = 0{,}933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.

Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum \lambda^2}{n}$$

Sum of squared loadings

$$\sum \lambda^2 = 6{,}70$$

with

$$n = 12$$

so

$$AVE = \frac{6{,}70}{12} = 0{,}558$$

AVE = 0,558
The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity.

In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). The results indicated a Construct Reliability (CR) value of 0.933, which is well above the recommended minimum threshold of 0.70. This finding demonstrates that the indicators exhibit excellent internal consistency in measuring the latent constructs investigated in this study.
Furthermore, the Average Variance Extracted (AVE) value of 0.558 indicates that more than 55% of the variance in the observed indicators is explained by their corresponding latent constructs. Since this value exceeds the recommended criterion of 0.50, the constructs demonstrate satisfactory convergent validity. These findings indicate that the observed indicators are not only valid based on their standardized factor loadings but also consistently represent the latent constructs they were designed to measure.
Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Structural Model Evaluation
After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data.
The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI

= 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, model reanalysis was conducted based on the diagnostic information provided by LISREL. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. All goodness-of-fit indices satisfied the recommended criteria, with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement.

The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

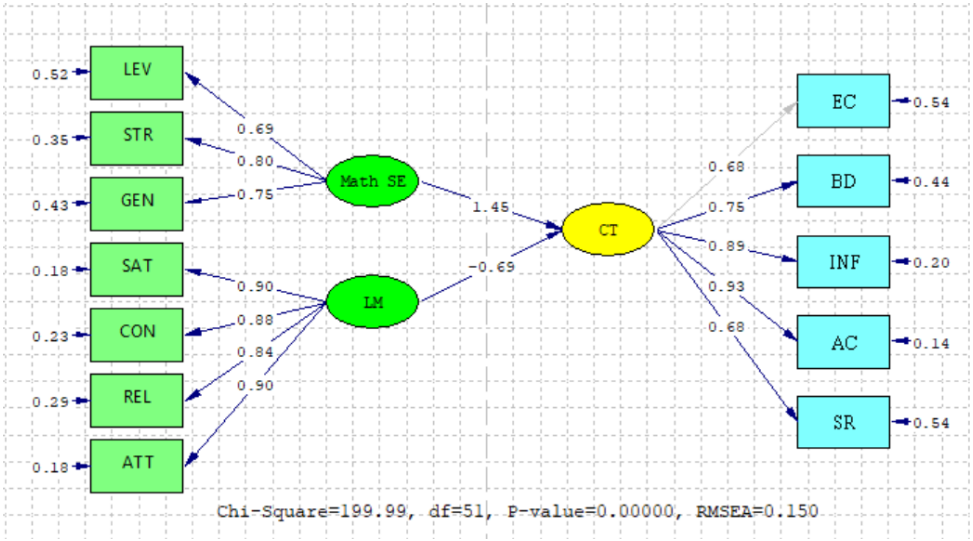


Figure 3. Model SEM

Tabel 3. Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,88	Not Good
2	GFI	≥ 90	0.88	Not Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good
5	RMSEA	≥ 0.08	0,150	Good

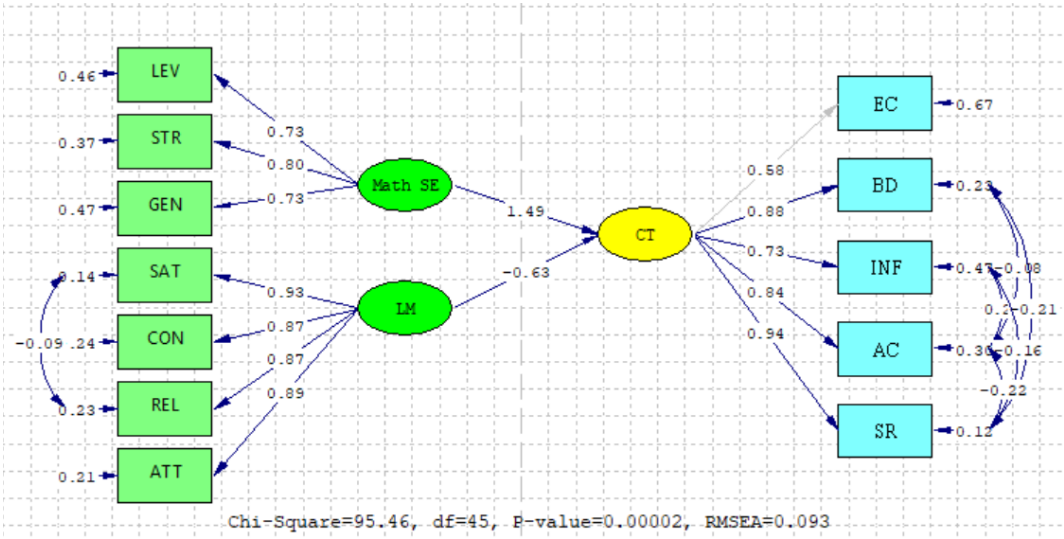


Figure 4. Reanalisis Model SEM

Tabel 4. Reanalisis Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,97	Good
2	CFI	≥ 90	0.98	Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≥ 0.08	0,093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero.

As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value (|−2.26| = 2.26) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction.

These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the proposed structural relationships were empirically supported based on the significance of the estimated t-values.

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level.

As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Regarding the structural relationships, the path from Mathematical Self-Efficacy to Critical Thinking yielded a t-value of 4.40, indicating a positive and statistically significant effect. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold (|−2.26| > 1.96), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy.

Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

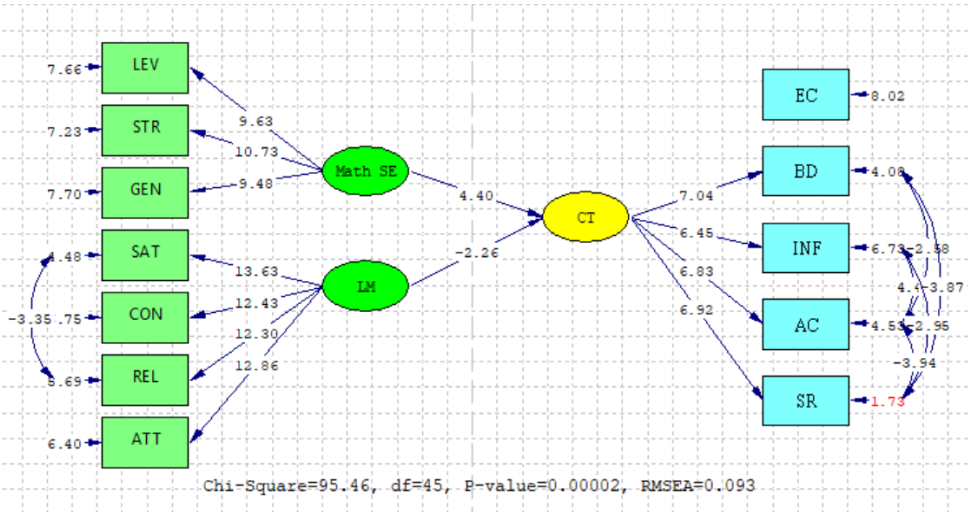


Figure 5. t-value Model SEM

DISCUSSION

The findings of this study indicate that students' critical thinking skills are determined not only by their mastery of mathematical concepts but also by their beliefs and internal drives when confronting mathematical problems. The proposed structural model identifies learning motivation and mathematical self-efficacy as two affective factors that explain students' ability to clarify problems, use evidence as a basis for judgment, draw inferences, provide further explanations, and determine appropriate problem-solving strategies. Following model refinement, the structural model demonstrated a substantially improved fit to the empirical data, as reflected by NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94. In addition, the reduction in RMSEA from 0.150 to 0.093 indicates that the discrepancy between the theoretical model and the observed data was considerably reduced.

Although the RMSEA value remains above the threshold for a close fit, it falls within the range generally considered to represent an acceptable or marginal model fit, thereby supporting the use of the revised model for hypothesis testing.

Structure of the Learning Motivation Construct

The construct of learning motivation was represented by four indicators: attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. These values indicate that all four indicators provide strong representations of students' learning motivation. Among them, attention and satisfaction exhibited the highest factor loadings (0.90), suggesting that students' motivation is primarily reflected in their ability to maintain attention during learning activities and in the satisfaction they experience after completing mathematical tasks or participating in classroom learning.

The prominence of the attention indicator suggests that students' initial engagement plays a fundamental role in sustaining learning motivation. Students who are able to focus their attention tend to be more receptive to new information, actively participate in problem-solving processes, and remain engaged throughout learning activities. Likewise, the strong contribution of satisfaction indicates that experiences of success, recognition, and perceived learning benefits reinforce students' motivation. These findings imply that learning motivation is not merely an antecedent of learning but is continuously strengthened through positive learning experiences and successful task completion.

The confidence indicator produced a standardized loading factor of 0.88. Although confidence is conceptualized as one of the four dimensions of the ARCS motivational model, it differs conceptually from mathematical self-efficacy, which constitutes a separate latent construct in this study. Within the ARCS framework, confidence reflects students' general expectations of success during the learning process, whereas mathematical self-efficacy refers to students' beliefs about their capability to perform specific mathematical tasks successfully. This conceptual proximity should be carefully considered because it may generate empirical overlap between learning motivation and mathematical self-efficacy. Such overlap provides a plausible explanation for why the structural path from learning motivation to critical thinking became negative when both constructs were estimated simultaneously within the same structural model.

The present findings are consistent with the study conducted by In'am and Sutrisno, who reported that the Teams Games Tournament (TGT) cooperative learning model enhanced both students' learning motivation and mathematical self-efficacy through intensive peer interaction and shared experiences of success (In'am & Sutrisno, 2021). Their findings also suggest that learning motivation and self-efficacy tend to develop simultaneously during instructional activities, making the two constructs difficult to distinguish empirically. Consequently, when both variables are incorporated into a single structural equation model, a degree of conceptual and statistical overlap may occur, potentially influencing the direction and magnitude of the estimated structural coefficients.

Struktur konstruk self-efficacy matematis

Mathematical self-efficacy was measured using three indicators: level, strength, and generality, with standardized factor loadings of 0.69, 0.80, and 0.75, respectively. Among these dimensions, strength emerged as the strongest indicator of mathematical self-efficacy. This finding suggests that students' self-efficacy is primarily reflected in the strength of their belief that they can persist when confronted with mathematical challenges, rather than merely in their willingness to undertake tasks of varying levels of difficulty.

The dominance of the strength dimension has important implications for the development of critical thinking skills. Solving mathematical problems that require critical thinking rarely leads to immediate solutions. Instead, students are often required to test alternative strategies, identify and correct errors, revise their approaches, and continuously evaluate the appropriateness of their solutions. Under such circumstances, the strength of students' self-beliefs determines whether they remain engaged in the problem-solving process or abandon their efforts after encountering initial failure. Therefore, mathematical self-efficacy should be viewed not simply as a positive perception of one's own abilities, but as a psychological resource that sustains persistence and supports higher-order cognitive processes during complex mathematical reasoning.

The generality dimension, with a standardized loading of 0.75, indicates that students with higher mathematical self-efficacy tend to transfer their confidence across different mathematical contexts. In contrast, the level dimension exhibited the lowest loading (0.69), suggesting that students' confidence in dealing with progressively more difficult mathematical tasks is relatively weaker than their determination to persist. In other words, students may remain motivated to continue working on mathematical problems, yet their confidence may decline as the complexity of the tasks increases substantially.

These findings are consistent with the study by Yulianto, Umami, and Mony, who reported that mathematical self-efficacy makes a significant contribution to students' critical thinking skills. Their study further demonstrated that the influence of self-efficacy is moderated by the instructional approach adopted in the classroom, highlighting the interaction between affective and pedagogical factors in promoting higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Mawaddah et al., 2026; Sudiartini et al., 2025). Similarly, Yang, Maeda, and Gentry, using data from the National Assessment of Educational Progress (NAEP), identified mathematical self-efficacy as a robust predictor of mathematics achievement across different grade levels, even after controlling for student- and school-level characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these studies support the view that mathematical self-efficacy represents a proximal psychological factor that directly influences students' cognitive engagement and their capacity to think critically when solving mathematical problems.

Structure of the Critical Thinking Construct

The construct of critical thinking was represented by five indicators: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The standardized factor loadings ranged from 0.68 to 0.93, indicating that all indicators made meaningful contributions to the latent construct. Among these dimensions, advanced clarification exhibited the highest loading (0.93), followed by inference (0.89). These findings suggest that students' critical thinking skills are most strongly reflected in their ability to provide well-reasoned explanations and to draw logical conclusions based on the information available and the problem-solving processes they employ.

The prominence of advanced clarification indicates that critical thinking extends beyond simply obtaining correct answers. Rather, it is demonstrated through students' ability to justify the strategies they select, establish logical connections among relevant information, identify underlying assumptions, and clarify the reasoning that supports their conclusions. In mathematics education, this dimension is particularly important because a correct numerical answer does not necessarily reflect a deep conceptual understanding. Students may arrive at the correct solution by applying memorized procedures, yet still be unable to explain why those procedures are appropriate or mathematically justified. Therefore, encouraging students to articulate their reasoning is an essential component of fostering higher-order thinking.

The strong loading of the inference dimension further highlights that drawing logical conclusions constitutes a central component of critical thinking within the proposed model. Students are expected not only to perform mathematical calculations but also to interpret the results, evaluate the available evidence, and formulate conclusions that are logically coherent and mathematically defensible. This finding suggests that critical thinking progresses from understanding and processing information toward constructing reasoned judgments supported by evidence.

In contrast, elementary clarification and strategy and reflection exhibited the lowest standardized loadings (0.68 each). Although both indicators remained statistically significant and met the acceptable validity criteria, their relatively lower contributions suggest that students are less proficient in identifying the core elements of a problem and critically evaluating their own solution strategies than they are in explaining reasoning and drawing inferences. The comparatively weaker contribution of strategy and reflection may indicate that many students tend to stop once they obtain an answer, without verifying the accuracy of their reasoning, considering alternative solution strategies, or reflecting on the efficiency and appropriateness of their problem-solving process. Such tendencies may limit the development of deeper metacognitive skills that are fundamental to effective mathematical reasoning.

These findings have important implications for mathematics instruction. Developing students' critical thinking skills requires more than presenting increasingly difficult mathematical problems.

Teachers should create learning environments that encourage students to identify relevant information, clarify problem requirements, compare alternative solution strategies, justify their reasoning, and critically evaluate the validity and efficiency of their solutions. Contextual and problem-based learning effectively promotes critical thinking by providing students with meaningful opportunities to analyze real-world situations, select appropriate strategies, justify their reasoning, and reflect on the quality of their solutions (Anggraeni et al., 2023; Yu & Zin, 2023). Such instructional approaches not only improve mathematical performance but also cultivate the reflective and analytical thinking processes that characterize effective critical thinkers.

The Effect of Mathematical Self-Efficacy on Critical Thinking Skills

The structural analysis indicates that mathematical self-efficacy has a positive and significant effect on critical thinking skills, with a T-value of 4.40. These findings confirm that students' belief in their ability to solve math problems plays a significant role in supporting higher-order thinking activities. Students with strong self-efficacy tend to be better prepared to tackle non-routine problems, persevere when encountering obstacles, and use mistakes as a basis for refining their strategies.

This influence can be explained by the close relationship between self-efficacy and the task-solving process. Critical thinking requires sustained cognitive engagement, while self-efficacy determines the extent to which students are willing to activate and maintain that engagement. When students are confident in their ability to solve problems, their cognitive resources are more likely to be directed toward problem analysis rather than toward anxiety, doubt, or the desire to avoid the task. Self-efficacy makes a significant contribution to mathematical critical thinking ability (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). These findings are also consistent with research showing that self-efficacy is a strong predictor of mathematics achievement from elementary through high school. Although mathematical achievement differs from critical thinking, both findings point to a similar mechanism: belief in one's own abilities supports the courage to make decisions, sustain effort, and manage difficulties in mathematical tasks.

Mathematical self-efficacy and mathematical thinking are the closest direct predictors of problem-solving ability. In their model, motivation functions as an upstream factor, while its influence on problem-solving is mediated through more proximal processes, particularly self-efficacy and mathematical thinking. These findings help explain the results of this study, which show that self-efficacy has a stronger direct influence on critical thinking than learning motivation.

Relationship Between Learning Motivation and Critical Thinking Skills

The structural path from Learning Motivation to Critical Thinking yielded a t-value of −2.26. Because the absolute value exceeds the critical threshold of 1.96, the relationship is statistically significant; however, the estimated effect is negative. This finding should not be interpreted as evidence that learning motivation inherently diminishes students' critical thinking skills. Rather, the negative coefficient should be understood within the context of the structural model, in which mathematical self-efficacy was simultaneously included as a predictor.

When examined independently, learning motivation is generally expected to be positively associated with students' engagement in learning activities. However, after controlling for the variance shared with mathematical self-efficacy, the unique contribution of learning motivation may exhibit a different relationship with critical thinking. This pattern may reflect a suppression effect or substantial conceptual overlap between the two constructs, particularly because the confidence dimension of the ARCS motivational model is conceptually related to mathematical self-efficacy. Consequently, the negative coefficient should not be interpreted as suggesting that attention, relevance, satisfaction, or the desire to learn are detrimental to critical thinking. Instead, it indicates that learning motivation, in the absence of strong beliefs about one's mathematical competence, may not necessarily translate into effective critical thinking performance.

Students may demonstrate high levels of attention, perceive mathematics as relevant, and possess a strong desire to achieve positive learning outcomes, yet still struggle when required to select appropriate problem-solving strategies, tolerate uncertainty, or justify mathematical reasoning. Under these circumstances, learning motivation provides the impetus to engage in learning, whereas mathematical self-efficacy determines whether this motivation can be transformed into effective cognitive action. Therefore, learning motivation can be viewed as the factor that initiates students'

engagement, while mathematical self-efficacy functions as the proximal operational belief that enables students to persist, regulate their efforts, and successfully perform complex mathematical tasks.

This interpretation is consistent with previous research suggesting that learning motivation functions as an upstream motivational predictor, whereas self-efficacy serves as a more proximal psychological mechanism underlying successful problem solving (Bandura, 1982, 2014; Schunk, 1984). Likewise, In'am and Sutrisno reported that cooperative learning experiences simultaneously enhance students' learning motivation and mathematical self-efficacy, indicating that the two constructs tend to develop together rather than independently (Holenstein et al., 2022; Stevens et al., 2004; Zimmerman, 2000). These findings imply that instructional interventions should extend beyond increasing students' interest in learning by providing authentic mastery experiences that transform motivation into confidence in mathematical competence.

Nevertheless, the negative structural coefficient should be interpreted with caution. The standardized structural model produced coefficients of 1.45 for the path from Mathematical Self-Efficacy to Critical Thinking and −0.69 for the path from Learning Motivation to Critical Thinking. A standardized coefficient exceeding 1.00 may indicate statistical issues such as multicollinearity, a suppression effect, excessively high correlations among predictors, or an improper estimation solution, including the possibility of a Heywood case. Therefore, before drawing substantive conclusions, it is important to examine the correlation between learning motivation and mathematical self-efficacy, the associated standard errors, the covariance matrix, and other diagnostic information provided by LISREL. Without these additional evaluations, the magnitude of the positive effect of self-efficacy and the negative effect of learning motivation may be overinterpreted.

The refinement of the structural model improved its overall fit by allowing correlations among several measurement errors based on the diagnostic information generated by LISREL. Statistically, this procedure substantially improved the model's goodness-of-fit indices. However, correlated error terms should be introduced only when supported by substantive theoretical justification rather than solely to improve model fit. Within the learning motivation construct, correlated errors may arise because certain questionnaire items share similar wording, contexts, or response patterns. Likewise, correlated errors among the critical thinking indicators may occur because several dimensions were assessed using related mathematical tasks or common problem-solving processes, resulting in shared variance that is not fully explained by the general latent construct.

Overall, the model refinement did not alter the underlying theoretical assumption that both learning motivation and mathematical self-efficacy are associated with students' critical thinking skills. Instead, it suggests that the relationships among the observed indicators are more complex than initially assumed, particularly when the independence of measurement errors is relaxed. Although the refined model demonstrates a substantially better fit to the empirical data, the RMSEA value of 0.093 indicates that some degree of model misfit remains. Accordingly, the final model is more appropriately described as exhibiting an acceptable (or marginal) fit rather than an excellent or close fit.

Theoretical and Educational Implications

The primary theoretical contribution of this study lies in distinguishing the roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills. Although both constructs represent important affective dimensions of learning, they operate through different psychological mechanisms. Learning motivation explains why students are willing to participate in learning activities, whereas mathematical self-efficacy explains whether students believe they possess the capability to perform the cognitive tasks required. In the context of mathematical critical thinking, this operational belief appears to be more directly associated with analyzing information, selecting appropriate strategies, drawing logical conclusions, and sustaining effort throughout complex problem-solving processes. From a pedagogical perspective, these findings suggest that mathematics instruction should extend beyond making learning activities interesting or personally relevant. Teachers should intentionally foster students' mathematical self-efficacy by providing challenging yet attainable tasks, offering graduated instructional support, delivering strategy-oriented feedback, incorporating peer modeling, and creating opportunities for students to learn

from and correct their mistakes. Contextual and problem-based learning approaches can effectively support these objectives, provided that the complexity of mathematical tasks is carefully calibrated to ensure that students experience genuine mastery rather than repeated failure. Previous studies have similarly shown that contextual and problem-based learning simultaneously promotes critical thinking and strengthens students' mathematical self-efficacy (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024b).

Particular attention should also be given to the relatively weaker dimensions of critical thinking identified in this study, namely elementary clarification and strategy and reflection. Teachers can strengthen these dimensions by routinely encouraging students to ask reflective questions such as: What information is provided? What is actually being asked? Why is this strategy appropriate? Are there alternative approaches? How can the correctness of the solution be verified? Such reflective practices are likely to strengthen the relationship between students' self-efficacy and the quality of their mathematical reasoning, ensuring that confidence is accompanied by genuine conceptual understanding and effective problem-solving competence.

Overall, the findings of this study indicate that mathematical self-efficacy represents the affective factor most directly associated with students' critical thinking skills. Although learning motivation remains an essential component of successful learning, its influence should be understood within a broader psychological framework in which its effects may operate through mathematical self-efficacy, self-regulated learning, persistence, and cognitive engagement during problem solving. Consequently, fostering students' critical thinking requires instructional approaches that simultaneously cultivate the desire to learn, strengthen confidence in mathematical competence, and develop habits of reflective and analytical thinking.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently.

Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self-efficacy. Teachers are encouraged to design learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the research involved a relatively small sample of 34 eighth-grade students from a single junior high school, limiting the generalizability of the findings to broader educational contexts. Second, the study focused exclusively on the Pythagorean theorem, meaning that the structural relationships identified may differ when applied to other mathematical topics with different cognitive characteristics. Third, the research adopted a cross-sectional design, which captures relationships among variables at a single point in time and therefore does not explain how learning motivation, mathematical self-efficacy, and critical thinking develop longitudinally. Finally, although the reanalyzed SEM model achieved acceptable goodness-of-fit indices, the RMSEA value (0.093) indicates that there is still room for improving the structural model by considering additional variables or alternative model specifications.

Suggestions

Future research is recommended to involve larger and more diverse samples from different schools and educational levels to improve the generalizability of the findings. Longitudinal or experimental studies are also needed to examine the causal development of critical thinking and to evaluate how instructional interventions enhance mathematical self-efficacy over time. In addition, future studies should incorporate other psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, problem-solving strategies, or classroom learning environment, to obtain a more comprehensive explanation of students' critical thinking skills.

From a practical perspective, mathematics teachers are encouraged to prioritize instructional strategies that strengthen students' mathematical self-efficacy through meaningful problem-solving experiences, guided practice, reflective discussion, and constructive feedback. Rather than merely increasing students' motivation to learn, instructional practices should cultivate confidence in applying mathematical knowledge, as this study indicates that mathematical self-efficacy is the affective factor most directly associated with students' critical thinking skills.

Conclusion

This study investigated the structural relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using Structural Equation Modeling (SEM). The measurement model demonstrated satisfactory psychometric properties, as evidenced by adequate sampling adequacy, acceptable construct validity, and high construct reliability. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data.

The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence, analytical reasoning, and reflective thinking when confronting complex mathematical tasks.

The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

References

Agusman, Purwanto, & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the Relationship between Academic Self-motivation and the Mathematical Thinking: A Case Study of Secondary School Students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101334

Aulia, H. D., Umbara, D., Jupri, A., & Dahlan, J. A. (2025). Mathematical Critical Thinking Ability of Grade IX Students in Solving Ill-Structured Problems. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1), 185–194. https://doi.org/10.30998/formatif.v15i1.27337

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the Impact of Discovery Learning and Self-Efficacy on Students' Critical Thinking Skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4).

https://doi.org/10.35445/alishlah.v17i4.7134
Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122.
Bandura, A. (2014). Exercise of personal agency through the self-efficacy mechanism. In *Self-efficacy* (pp. 3–38). Taylor & Francis.
Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807
Cahyani, V. F., & Setyaningsih, R. (2024). The Implementation of Problem-Based Learning to Enhance Critical Thinking Skills in Solving Contextual Mathematics Problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29
Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement Model and Adaptation of Self-Efficacy toward Mathematics Reasoning among University Students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114
Farah Deeba, Sana Hafeez, Shazia Noureen. (2021). AN INVESTIGATION OF 10th GRADE STUDENTS' SELF-EFFICACY BELIEFS IN MATHEMATICS. *Pakistan Journal of Educational Research*, *4*(1). https://doi.org/10.52337/pjer.v4i1.145
Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007
Holenstein, M., Bruckmaier, G., & Grob, A. (2022). How do self-efficacy and self-concept impact mathematical achievement? The case of mathematical modelling. *British Journal of Educational Psychology*, *92*(1), e12443.
In'am, A., & Sutrisno, E. S. (2021). Strengthening Students' Self-Efficacy and Motivation in Learning Mathematics through the Cooperative Learning Model. *International Journal of Instruction*, *14*(1), 395–410.
Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2394738
Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140
Marlena, L., & Nugraheni, E. A. (2026). The Correlation Between Self-Efficacy and Critical Thinking Skills of Senior High School Students on the Pythagorean Theorem Material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587
Masitoh, L. F., & Fitriyani, H. (2018). Improving students' mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30.
Mawaddah, S., Syahri, M., & Soenaryo, S. F. (2026). The Application of Guided Inquiry to Students' Critical Thinking Skills in Pancasila Education Subjects with Self-Efficacy As a Moderator Variable. *Scaffolding: Jurnal Pendidikan Islam Dan Multikulturalisme*, *8*(1), 225–244. https://doi.org/10.37680/scaffolding.v8i1.8520
Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-Efficacy, Reflective Thinking, and Critical Thinking: A Structural Equation Modeling Study Among Adolescents. *Islamic Guidance and Counseling Journal*, *8*(2). https://doi.org/10.25217/0020258684000
Pajares, F., & Miller, M. D. (1995). Mathematics Self-Efficacy and Mathematics Performances: The Need for Specificity of Assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022-0167.42.2.190
Paudel, K. C., & Ghimire, S. P. (2024). Mathematics Self-efficacy among Secondary Level Students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130.
Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievementA multilevel analysis of the Programme for International Student Assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014
Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' Mathematical Creative Thinking and Learning Obstacles in Solving Ill-Structured Exponential Problems. *Jurnal Didaktik Matematika*, *12*(1),

53–74. https://doi.org/10.24815/jdm.v12i1.43834

Schunk, D. H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist*, *19*(1), 48–58.

Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033

Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of mathematics self-efficacy and motivation in mathematics performance across ethnicity. *The Journal of Educational Research*, *97*(4), 208–222.

Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? *Psychology, Evaluation, and Technology in Educational Research*, *7*(2), 292–302. https://doi.org/10.33292/petier.v7i2.304

Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How Students' Self-Efficacy Can Affect Their Mathematical Critical Thinking Ability? *(Jiml) Journal of Innovative Mathematics Learning*, *8*(3), 381–387. https://doi.org/10.22460/jiml.v8i3.26650

Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11*. https://doi.org/10.3389/feduc.2026.1696182

Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 1–29. https://doi.org/10.1186/s40536-024-00204-z

Yousuf, M. I., & Rajeswari, G. (2024). Relationship between Mathematics Self Efficacy and Mathematics Achievement. *International Journal of Emerging Knowledge Studies*, *03*(10), 797–802. https://doi.org/10.70333/ijeks-03-10-011

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Yulianto, D., Umami, M. R., & Mony, R. S. (2024a). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yulianto, D., Umami, M. R., & Mony, R. S. (2024b). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012023

Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.986622

Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

2. Revisi Reviewer 1 dan 2

Journal of Advanced Sciences and Mathematics Education
Volume X, Issue X, xx -xx.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index

Mathematical Self-Efficacy Outweighs Learning Motivation in Predicting Students' Critical Thinking Skills

Article Info

Article history:

Received: Month XX, 20XX
Revised: Month XX, 20XX
Accepted: Month XX, 20XX
(Cambria 9)

Keywords:

Critical Thinking Skills
Motivation to Learn
Maths Self-Efficacy

Abstract

ABSTRACT

Background of study: Critical thinking is an essential competency that enables students to analyse information, justify strategies, draw logical conclusions, and reflect on solutions when solving mathematical problems. Its development is influenced not only by cognitive mastery but also by affective factors, particularly learning motivation and mathematical self-efficacy. Although both constructs are frequently associated with mathematical performance, their relative contributions to students' critical thinking remain insufficiently explained.

Aims and scope of paper: This study aims to examine the structural relationships between learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving mathematical problems related to the Pythagorean theorem. It also compares the relative effects of learning motivation and mathematical self-efficacy on critical thinking.

Methods: A quantitative cross-sectional correlational design was employed. The population comprised 76 eighth-grade students at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Indonesia. A total of 34 students, consisting of 17 males and 17 females, were selected through simple random sampling. Data were collected using a learning motivation questionnaire based on the ARCS model, a mathematical self-efficacy questionnaire covering level, strength, and generality, and a critical thinking test based on Ennis' indicators. The data were analysed using Confirmatory Factor Analysis and Structural Equation Modeling with LISREL 8.80.

Result: The KMO value of 0.892 and a significant Bartlett's Test confirmed the suitability of the data for factor analysis. All indicators had factor loadings above 0.50 and significantly represented their respective constructs. Following model reanalysis, the structural model achieved acceptable fit, with NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, and RMSEA = 0.093. Mathematical self-efficacy had a positive and significant effect on critical thinking (t = 4.40), whereas learning motivation showed a significant negative relationship (t = −2.26).

Conclusion: Mathematical self-efficacy plays a more proximal and dominant role in supporting students' critical thinking than learning motivation. Students' confidence and persistence in performing mathematical tasks appear to be more directly connected to critical reasoning than their general willingness to learn.

To cite this article: Author. (20XX). Title. *Journal of Advanced Sciences and Mathematics Education, X*(X), XX-XX

INTRODUCTION

Critical thinking has become an essential competence in mathematics education because students are expected not only to obtain correct answers but also to examine information, justify strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Aulia et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). In such situations, students must understand the problem, identify relevant information, connect mathematical concepts, compare alternative strategies, and reflect on the reasonableness of their solutions. Nevertheless, many students still experience difficulties in analysing mathematical problems, explaining the basis of their answers, and selecting appropriate problem-solving strategies. These conditions indicate that the development of critical thinking remains an important challenge in secondary mathematics education.

Students' critical thinking performance is influenced not only by cognitive knowledge but also by affective factors that shape how they approach challenging tasks. Two factors frequently associated with mathematical learning are learning motivation and mathematical self-efficacy. Learning

Commented [1]: The title is engaging, but "outweighs" conveys a rather definitive comparison. Given the small sample, the cross-sectional design, and the unusual standardised coefficient reported later, a slightly more cautious title may be appropriate, such as "Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills."

Commented [2]: Please briefly acknowledge that the SEM analysis was conducted with a relatively small sample. This does not necessarily invalidate the study, but readers should be informed that the model should be interpreted as preliminary or exploratory.

Commented [3]: One reported loading is exactly 0.50 rather than above 0.50. Please revise this to "factor loadings of 0.50 or higher." This small adjustment will make the abstract consistent with Table 2.

Commented [4]: The terms "dominant" and "supporting" may be stronger than the cross-sectional evidence permits, particularly because the standardised coefficient exceeds 1.00. Please consider "was more strongly associated with critical thinking within the estimated model."

motivation encourages students to participate, persist, and direct their efforts towards learning goals. Motivated students are generally expected to show greater attention, perseverance, and willingness to solve difficult problems. However, empirical evidence concerning the relationship between motivation and mathematical thinking has not always been consistent. Alotaibi, for example, found that academic self-motivation showed limited or no dependence on the mathematical thinking of secondary school students (Alotaibi, 2020). This finding suggests that students' willingness to learn may not automatically translate into the ability to analyse, evaluate, and solve mathematical problems critically.

Mathematical self-efficacy refers to students' beliefs about their capacity to perform mathematical tasks successfully (Chan et al., 2022; Farah Deeba, Sana Hafeez, Shazia Noureen, 2021; Pajares & Miller, 1995; et al., 2024; Yuliyanto et al., 2021; Zakariya, 2022). Unlike general interest or willingness to learn, self-efficacy is closely related to students' judgments about whether they can organise and carry out the actions required to solve a particular problem. Students with strong self-efficacy are more likely to attempt challenging questions, maintain effort after experiencing difficulty, test alternative strategies, and interpret mistakes as part of the learning process. Conversely, students who doubt their mathematical capabilities may avoid complex tasks, rely excessively on procedural routines, or abandon problem-solving efforts prematurely. Recent research shows that mathematics self-efficacy among secondary students varies across groups and educational levels, emphasising the need for systematic support to strengthen students' confidence in learning mathematics (Paudel & Ghimire, 2024).

Previous studies have provided evidence of a positive relationship between self-efficacy and mathematical critical thinking. Yulianto et al. reported that self-efficacy contributed significantly to students' critical mathematical thinking and interacted with the instructional approach used in mathematics classrooms (Yulianto et al., 2024a). Similarly, Marlena and Nugraheni found a strong positive correlation between self-efficacy and critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). These findings indicate that students' confidence in their mathematical capabilities may serve as an important affective foundation for engaging in complex reasoning. However, much of the existing research has examined self-efficacy in relation to critical thinking as a single association, compared critical thinking across self-efficacy levels, or investigated self-efficacy within particular instructional interventions.

This leaves several important gaps. First, motivation and mathematical self-efficacy are often studied separately, even though both constructs may operate simultaneously when students confront difficult mathematical problems. Consequently, the relative contribution of each construct to critical thinking is not yet sufficiently explained. Second, correlational evidence showing that motivation or self-efficacy is associated with critical thinking does not necessarily clarify whether each variable retains a meaningful contribution when both are included in the same model. Third, existing studies commonly assume that high learning motivation naturally supports higher-order thinking, while giving less attention to the possibility that motivation may be related to critical thinking at the bivariate level but lose its explanatory power after mathematical self-efficacy is considered. Fourth, studies focusing specifically on students' critical thinking when solving Pythagorean problems remain limited, even though this topic requires students to interpret problem situations, determine relevant relationships, select strategies, and justify mathematical conclusions.

Accordingly, the novelty of this study lies in examining learning motivation and mathematical self-efficacy simultaneously and comparing their relative roles as predictors of students' critical thinking skills. Rather than merely determining whether both affective variables correlate with critical thinking, this study investigates which construct provides the stronger direct contribution when the variables are analysed within the same structural model. This comparative perspective is important because students may possess a strong desire to learn but still hesitate when they do not believe that they can complete a mathematical task successfully. Thus, the study distinguishes between students' willingness to engage in learning and their confidence in performing the cognitive actions required for critical problem solving.

This study therefore aims to analyse the direct and simultaneous effects of learning motivation and mathematical self-efficacy on students' critical thinking skills in solving mathematics problems. Specifically, it addresses three questions: whether learning motivation significantly predicts students' critical thinking skills, whether mathematical self-efficacy significantly predicts students'

Commented [5]: Because this is a cross-sectional correlational study, "effects" may imply causality. Please use "associations," "relationships," or "predictive contributions" consistently throughout the manuscript.

critical thinking skills, and how strongly the two variables jointly explain variations in critical thinking. By clarifying their relative contributions, the findings are expected to provide a more precise basis for designing mathematics instruction that not only stimulates students' interest and persistence but also strengthens their confidence in analysing, reasoning, and solving challenging mathematical problems.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participants

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected through simple random sampling to ensure that every student had an equal probability of participation.

Prior to data collection, students and the school administration were informed about the objectives of the study, and participation was voluntary. All collected data were treated confidentially and used solely for research purposes.

Instruments

Three research instruments were employed.

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, consisting of four dimensions: Attention, Relevance, Confidence, and Satisfaction. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework. The instrument measured three dimensions:

a. Level
b. Strength
c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks with varying levels of complexity.

Critical Thinking Test

Students' critical thinking skills were measured using essay-type mathematical problems developed within the Pythagorean Theorem context. The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:

a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

Commented [6]: Please explain how the random selection was actually performed—for example, by random-number generator, lottery, or student identification numbers—and whether any selected students declined participation or had incomplete data.

Commented [7]: Please provide a brief justification for the sample size in relation to the complexity of the CFA and SEM models. A power analysis, parameter-to-sample consideration, or an explicit acknowledgement that the analysis is exploratory would strengthen the methodological transparency.

Commented [8]: Since the participants were minors, please clarify whether parental or guardian consent and student assent were obtained. Please also state whether the study received approval or exemption from an institutional ethics committee, where applicable.

Commented [9]: Please report the number of items, the source or development procedure, representative item examples, scoring direction, and whether any negatively worded items were reverse-coded. Reliability should also be reported specifically for this construct.

Commented [10]: Please identify the original instrument or adaptation source and explain the adaptation process. The number of items per dimension, response scale, scoring procedure, and evidence of linguistic or cultural adaptation should be included.

Commented [11]: Please report the number of problems, score range, scoring rubric, time allocation, and at least one example of the task format. Because essay responses require judgement, please also state who scored them and whether inter-rater reliability was evaluated.

All instruments underwent expert judgment by mathematics education specialists prior to implementation to establish content validity.

Commented [12]: Please specify the number and qualifications of the experts, the criteria they evaluated, and how agreement was determined. Reporting an index such as Aiken's V, CVI, or percentage agreement would make this statement more informative.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, several statistical assumptions were evaluated, including normality, linearity, homogeneity, and multicollinearity.

Commented [13]: The Methods section lists these assumptions, but the Results section does not report their outcomes. Please provide the relevant statistics, particularly multivariate normality and multicollinearity diagnostics, because they are important for interpreting the unusual structural coefficients.

he measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50.

Commented [14]: CR and AVE should normally be calculated and reported separately for learning motivation, mathematical self-efficacy, and critical thinking. The manuscript currently appears to provide one overall CR and AVE across all 12 indicators. Please clarify and preferably report construct-specific values.

The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual (SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values.

Commented [15]: Please identify the estimation method used, such as maximum likelihood, robust maximum likelihood, or another estimator. Also explain how ordinal Likert responses, missing values, and potential non-normality were handled.

Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 ($\alpha = 0.05$). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

Commented [16]: The manuscript states that R^2 was used, but the value does not appear in the Results section. Please report R^2 for critical thinking and ensure that it is discussed in relation to the third research question.

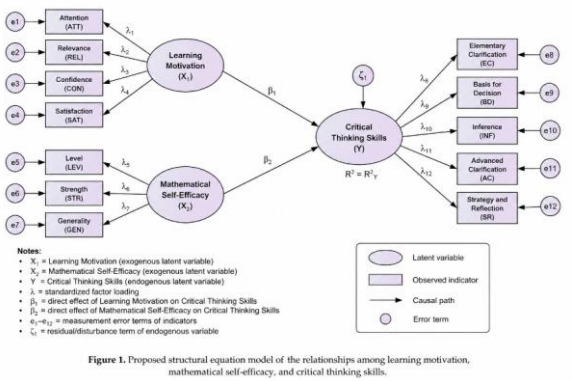


Figure 1. Proposed structural equation model of the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills.

RESULTS AND DISCUSSION

RESULTS

Preliminary Analysis

Descriptive Statistics

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were

Commented [17]: This subsection does not actually present descriptive statistics. Please add a concise table containing the mean, standard deviation, observed range, skewness, and possibly correlations for the principal variables, or rename the subsection if descriptive statistics were not calculated.

appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis.

The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test	Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result ($\chi^2 = 1307.307$, $df = 66$, $p < 0.001$), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis.

Overall, the results of the KMO measure and Bartlett's Test provide empirical evidence that the dataset satisfies the fundamental assumptions for conducting Confirmatory Factor Analysis (CFA). Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL.

Commented [18]: KMO and Bartlett's test indicate whether a correlation matrix is suitable for factor analysis, but they do not by themselves establish the adequacy of a confirmatory measurement model. Please soften this statement and rely primarily on CFA fit, loadings, reliability, and validity evidence.

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model.

Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

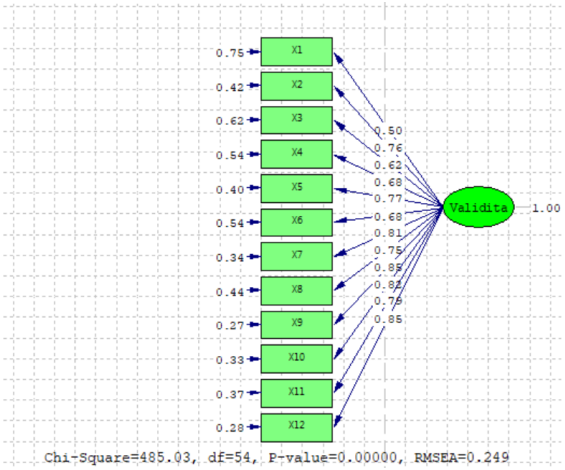


Figure 2. Uji CFA

Commented [19]: Please clarify what model Figure 2 represents. The figure appears to combine all indicators into one general factor labelled "Validitas," whereas the proposed study contains three distinct constructs. The figure also displays poor initial fit, including RMSEA = 0.249, which needs to be explained rather than followed immediately by a claim of satisfactory validity.

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor dan Error Variance

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Commented [20]: Please map X1–X12 to their respective constructs and named dimensions. Readers should not have to infer which indicators measure motivation, self-efficacy, or critical thinking. Please also use English throughout the caption and column headings.

Construct Reliability (CR)

Using the Fornell & Larcker (1981) formula:

$$CR = \frac{(\sum\lambda)^2}{(\sum\lambda)^2 + \sum\varepsilon}$$

Commented [21]: The formulas and intermediate calculations appear to be missing from the manuscript. Please insert the equations correctly or remove these incomplete fragments and present the final construct-specific results in a clear table.

Calculation results:

$$\sum\lambda = 8{,}58$$
$$(\sum\lambda)^2 = 73{,}62$$
$$\sum\varepsilon = 5{,}30$$

so that

$$CR = \frac{73{,}62}{73{,}62 + 5{,}30} = 0{,}933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.

Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum \lambda^2}{n}$$

Sum of squared loadings

$$\sum \lambda^2 = 6{,}70$$

with

$$n = 12$$

so

$$AVE = \frac{6{,}70}{12} = 0{,}558$$

AVE = 0,558
The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity.

In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). The results indicated a Construct Reliability (CR) value of 0.933, which is well above the recommended minimum threshold of 0.70. This finding demonstrates that the indicators exhibit excellent internal consistency in measuring the latent constructs investigated in this study.
Furthermore, the Average Variance Extracted (AVE) value of 0.558 indicates that more than 55% of the variance in the observed indicators is explained by their corresponding latent constructs. Since this value exceeds the recommended criterion of 0.50, the constructs demonstrate satisfactory convergent validity. These findings indicate that the observed indicators are not only valid based on their standardized factor loadings but also consistently represent the latent constructs they were designed to measure.
Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Commented [22]: Please clarify which construct this CR value represents. A single reliability value combining indicators from three conceptually distinct latent variables does not demonstrate the reliability of each construct individually.

Structural Model Evaluation
After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data.
The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI

= 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, model reanalysis was conducted based on the diagnostic information provided by LISREL. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. All goodness-of-fit indices satisfied the recommended criteria, with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement.

The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

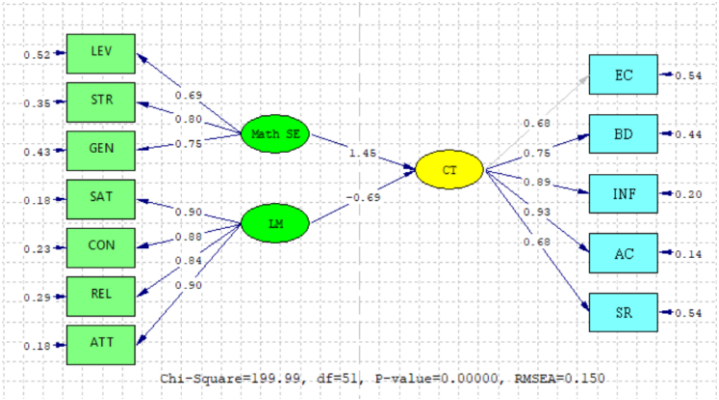


Figure 3. Model SEM

Tabel 3. Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,88	Not Good
2	GFI	≥ 90	0.88	Not Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good
5	RMSEA	≥ 0.08	0,150	Good

Commented [23]: Please report exactly which parameters were modified, which residuals were correlated, the relevant modification indices, and the theoretical justification for each change. "Diagnostic information" alone is not sufficient for readers to evaluate the respecification.

Commented [24]: This wording is slightly too strong because RMSEA = 0.093 represents marginal or acceptable fit rather than a clearly good fit. Please revise this to indicate that most incremental indices were good, while RMSEA remained marginal.

Commented [25]: Table 3 classifies RMSEA = 0.150 as "Good," whereas the surrounding narrative correctly describes it as high and indicative of poor fit. Please correct this decision and complete the currently empty "Cut of Value" column.

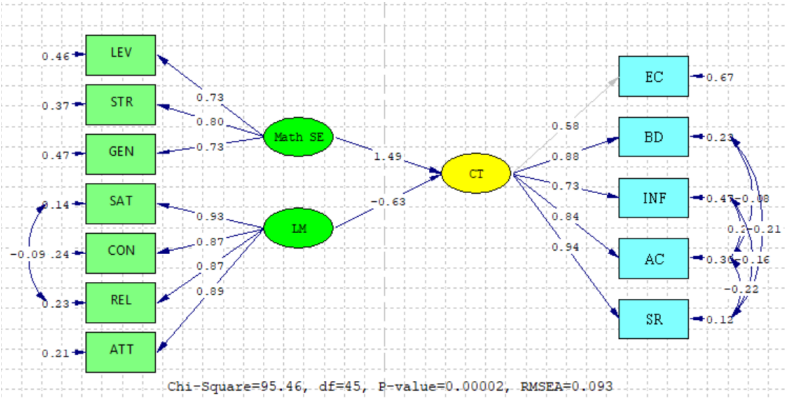


Figure 4. Reanalisis Model SEM

Tabel 4. Reanalisis Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,97	Good
2	CFI	≥ 90	0.98	Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≤ 0.08	0,093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero.

As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value (|−2.26| = 2.26) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction.

These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the proposed structural relationships were empirically supported based on the significance of the estimated t-values.

Commented [26]: Statistical significance alone does not mean that a hypothesised relationship was supported. If learning motivation was originally expected to have a positive effect, the significant negative coefficient does not support that directional hypothesis. Please distinguish between "statistically significant" and "supported in the hypothesised direction."

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level.

As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Regarding the structural relationships, the path from Mathematical Self-Efficacy to Critical Thinking yielded a t-value of 4.40, indicating a positive and statistically significant effect. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold (|−2.26| > 1.96), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy.

Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

Commented [27]: Please provide a table reporting the standardised coefficient, unstandardised coefficient, standard error, t-value, exact p-value, and confidence interval for each path. The t-value alone is not enough to judge the magnitude and precision of the relationship.

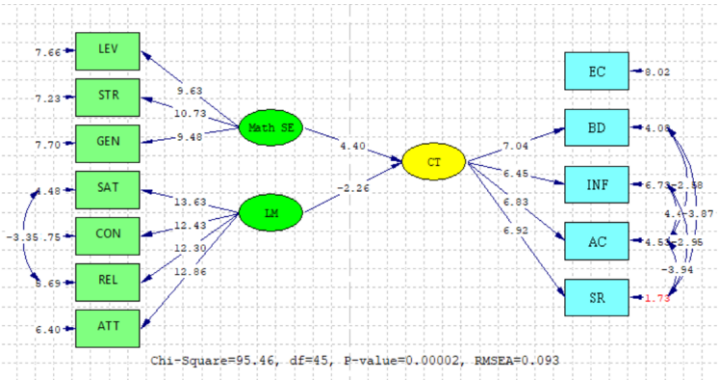


Figure 5. t-value Model SEM

DISCUSSION

The findings of this study indicate that students' critical thinking skills are determined not only by their mastery of mathematical concepts but also by their beliefs and internal drives when confronting mathematical problems. The proposed structural model identifies learning motivation and mathematical self-efficacy as two affective factors that explain students' ability to clarify problems, use evidence as a basis for judgment, draw inferences, provide further explanations, and determine appropriate problem-solving strategies. Following model refinement, the structural model demonstrated a substantially improved fit to the empirical data, as reflected by NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94. In addition, the reduction in RMSEA from 0.150 to 0.093 indicates that the discrepancy between the theoretical model and the observed data was considerably reduced.

Although the RMSEA value remains above the threshold for a close fit, it falls within the range generally considered to represent an acceptable or marginal model fit, thereby supporting the use of the revised model for hypothesis testing.

Structure of the Learning Motivation Construct

The construct of learning motivation was represented by four indicators: attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. These values indicate that all four indicators provide strong representations of students' learning motivation. Among them, attention and satisfaction exhibited the highest factor loadings (0.90), suggesting that students' motivation is primarily reflected in their ability to maintain attention during learning activities and in the satisfaction they experience after completing mathematical tasks or participating in classroom learning.

The prominence of the attention indicator suggests that students' initial engagement plays a fundamental role in sustaining learning motivation. Students who are able to focus their attention tend to be more receptive to new information, actively participate in problem-solving processes, and remain engaged throughout learning activities. Likewise, the strong contribution of satisfaction indicates that experiences of success, recognition, and perceived learning benefits reinforce students' motivation. These findings imply that learning motivation is not merely an antecedent of learning but is continuously strengthened through positive learning experiences and successful task completion.

The confidence indicator produced a standardized loading factor of 0.88. Although confidence is conceptualized as one of the four dimensions of the ARCS motivational model, it differs conceptually from mathematical self-efficacy, which constitutes a separate latent construct in this study. Within the ARCS framework, confidence reflects students' general expectations of success during the learning process, whereas mathematical self-efficacy refers to students' beliefs about their capability to perform specific mathematical tasks successfully. This conceptual proximity should be carefully considered because it may generate empirical overlap between learning motivation and mathematical self-efficacy. Such overlap provides a plausible explanation for why the structural path from learning motivation to critical thinking became negative when both constructs were estimated simultaneously within the same structural model.

The present findings are consistent with the study conducted by In'am and Sutrisno, who reported that the Teams Games Tournament (TGT) cooperative learning model enhanced both students' learning motivation and mathematical self-efficacy through intensive peer interaction and shared experiences of success (In'am & Sutrisno, 2021). Their findings also suggest that learning motivation and self-efficacy tend to develop simultaneously during instructional activities, making the two constructs difficult to distinguish empirically. Consequently, when both variables are incorporated into a single structural equation model, a degree of conceptual and statistical overlap may occur, potentially influencing the direction and magnitude of the estimated structural coefficients.

Struktur konstruk self-efficacy matematis

Mathematical self-efficacy was measured using three indicators: level, strength, and generality, with standardized factor loadings of 0.69, 0.80, and 0.75, respectively. Among these dimensions, strength emerged as the strongest indicator of mathematical self-efficacy. This finding suggests that students' self-efficacy is primarily reflected in the strength of their belief that they can persist when confronted with mathematical challenges, rather than merely in their willingness to undertake tasks of varying levels of difficulty.

The dominance of the strength dimension has important implications for the development of critical thinking skills. Solving mathematical problems that require critical thinking rarely leads to immediate solutions. Instead, students are often required to test alternative strategies, identify and correct errors, revise their approaches, and continuously evaluate the appropriateness of their solutions. Under such circumstances, the strength of students' self-beliefs determines whether they remain engaged in the problem-solving process or abandon their efforts after encountering initial failure. Therefore, mathematical self-efficacy should be viewed not simply as a positive perception of one's own abilities, but as a psychological resource that sustains persistence and supports higher-order cognitive processes during complex mathematical reasoning.

The generality dimension, with a standardized loading of 0.75, indicates that students with higher mathematical self-efficacy tend to transfer their confidence across different mathematical contexts. In contrast, the level dimension exhibited the lowest loading (0.69), suggesting that students' confidence in dealing with progressively more difficult mathematical tasks is relatively weaker than their determination to persist. In other words, students may remain motivated to continue working on mathematical problems, yet their confidence may decline as the complexity of the tasks increases substantially.

These findings are consistent with the study by Yulianto, Umami, and Mony, who reported that mathematical self-efficacy makes a significant contribution to students' critical thinking skills. Their study further demonstrated that the influence of self-efficacy is moderated by the instructional approach adopted in the classroom, highlighting the interaction between affective and pedagogical factors in promoting higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Mawaddah et al., 2026; Sudiartini et al., 2025). Similarly, Yang, Maeda, and Gentry, using data from the National Assessment of Educational Progress (NAEP), identified mathematical self-efficacy as a robust predictor of mathematics achievement across different grade levels, even after controlling for student- and school-level characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these studies support the view that mathematical self-efficacy represents a proximal psychological factor that directly influences students' cognitive engagement and their capacity to think critically when solving mathematical problems.

Structure of the Critical Thinking Construct

The construct of critical thinking was represented by five indicators: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The standardized factor loadings ranged from 0.68 to 0.93, indicating that all indicators made meaningful contributions to the latent construct. Among these dimensions, advanced clarification exhibited the highest loading (0.93), followed by inference (0.89). These findings suggest that students' critical thinking skills are most strongly reflected in their ability to provide well-reasoned explanations and to draw logical conclusions based on the information available and the problem-solving processes they employ.

The prominence of advanced clarification indicates that critical thinking extends beyond simply obtaining correct answers. Rather, it is demonstrated through students' ability to justify the strategies they select, establish logical connections among relevant information, identify underlying assumptions, and clarify the reasoning that supports their conclusions. In mathematics education, this dimension is particularly important because a correct numerical answer does not necessarily reflect a deep conceptual understanding. Students may arrive at the correct solution by applying memorized procedures, yet still be unable to explain why those procedures are appropriate or mathematically justified. Therefore, encouraging students to articulate their reasoning is an essential component of fostering higher-order thinking.

The strong loading of the inference dimension further highlights that drawing logical conclusions constitutes a central component of critical thinking within the proposed model. Students are expected not only to perform mathematical calculations but also to interpret the results, evaluate the available evidence, and formulate conclusions that are logically coherent and mathematically defensible. This finding suggests that critical thinking progresses from understanding and processing information toward constructing reasoned judgments supported by evidence.

In contrast, elementary clarification and strategy and reflection exhibited the lowest standardized loadings (0.68 each). Although both indicators remained statistically significant and met the acceptable validity criteria, their relatively lower contributions suggest that students are less proficient in identifying the core elements of a problem and critically evaluating their own solution strategies than they are in explaining reasoning and drawing inferences. The comparatively weaker contribution of strategy and reflection may indicate that many students tend to stop once they obtain an answer, without verifying the accuracy of their reasoning, considering alternative solution strategies, or reflecting on the efficiency and appropriateness of their problem-solving process. Such tendencies may limit the development of deeper metacognitive skills that are fundamental to effective mathematical reasoning.

These findings have important implications for mathematics instruction. Developing students' critical thinking skills requires more than presenting increasingly difficult mathematical problems.

Teachers should create learning environments that encourage students to identify relevant information, clarify problem requirements, compare alternative solution strategies, justify their reasoning, and critically evaluate the validity and efficiency of their solutions. Contextual and problem-based learning effectively promotes critical thinking by providing students with meaningful opportunities to analyze real-world situations, select appropriate strategies, justify their reasoning, and reflect on the quality of their solutions (Anggraeni et al., 2023; Yu & Zin, 2023). Such instructional approaches not only improve mathematical performance but also cultivate the reflective and analytical thinking processes that characterize effective critical thinkers.

The Effect of Mathematical Self-Efficacy on Critical Thinking Skills

The structural analysis indicates that mathematical self-efficacy has a positive and significant effect on critical thinking skills, with a T-value of 4.40. These findings confirm that students' belief in their ability to solve math problems plays a significant role in supporting higher-order thinking activities. Students with strong self-efficacy tend to be better prepared to tackle non-routine problems, persevere when encountering obstacles, and use mistakes as a basis for refining their strategies.

This influence can be explained by the close relationship between self-efficacy and the task-solving process. Critical thinking requires sustained cognitive engagement, while self-efficacy determines the extent to which students are willing to activate and maintain that engagement. When students are confident in their ability to solve problems, their cognitive resources are more likely to be directed toward problem analysis rather than toward anxiety, doubt, or the desire to avoid the task. Self-efficacy makes a significant contribution to mathematical critical thinking ability (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). These findings are also consistent with research showing that self-efficacy is a strong predictor of mathematics achievement from elementary through high school. Although mathematical achievement differs from critical thinking, both findings point to a similar mechanism: belief in one's own abilities supports the courage to make decisions, sustain effort, and manage difficulties in mathematical tasks.

Mathematical self-efficacy and mathematical thinking are the closest direct predictors of problem-solving ability. In their model, motivation functions as an upstream factor, while its influence on problem-solving is mediated through more proximal processes, particularly self-efficacy and mathematical thinking. These findings help explain the results of this study, which show that self-efficacy has a stronger direct influence on critical thinking than learning motivation.

Relationship Between Learning Motivation and Critical Thinking Skills

The structural path from Learning Motivation to Critical Thinking yielded a t-value of −2.26. Because the absolute value exceeds the critical threshold of 1.96, the relationship is statistically significant; however, the estimated effect is negative. This finding should not be interpreted as evidence that learning motivation inherently diminishes students' critical thinking skills. Rather, the negative coefficient should be understood within the context of the structural model, in which mathematical self-efficacy was simultaneously included as a predictor.

When examined independently, learning motivation is generally expected to be positively associated with students' engagement in learning activities. However, after controlling for the variance shared with mathematical self-efficacy, the unique contribution of learning motivation may exhibit a different relationship with critical thinking. This pattern may reflect a suppression effect or substantial conceptual overlap between the two constructs, particularly because the confidence dimension of the ARCS motivational model is conceptually related to mathematical self-efficacy. Consequently, the negative coefficient should not be interpreted as suggesting that attention, relevance, satisfaction, or the desire to learn are detrimental to critical thinking. Instead, it indicates that learning motivation, in the absence of strong beliefs about one's mathematical competence, may not necessarily translate into effective critical thinking performance.

Students may demonstrate high levels of attention, perceive mathematics as relevant, and possess a strong desire to achieve positive learning outcomes, yet still struggle when required to select appropriate problem-solving strategies, tolerate uncertainty, or justify mathematical reasoning. Under these circumstances, learning motivation provides the impetus to engage in learning, whereas mathematical self-efficacy determines whether this motivation can be transformed into effective cognitive action. Therefore, learning motivation can be viewed as the factor that initiates students'

engagement, while mathematical self-efficacy functions as the proximal operational belief that enables students to persist, regulate their efforts, and successfully perform complex mathematical tasks.

This interpretation is consistent with previous research suggesting that learning motivation functions as an upstream motivational predictor, whereas self-efficacy serves as a more proximal psychological mechanism underlying successful problem solving (Bandura, 1982, 2014; Schunk, 1984). Likewise, In'am and Sutrisno reported that cooperative learning experiences simultaneously enhance students' learning motivation and mathematical self-efficacy, indicating that the two constructs tend to develop together rather than independently (Holenstein et al., 2022; Stevens et al., 2004; Zimmerman, 2000). These findings imply that instructional interventions should extend beyond increasing students' interest in learning by providing authentic mastery experiences that transform motivation into confidence in mathematical competence.

Nevertheless, the negative structural coefficient should be interpreted with caution. The standardized structural model produced coefficients of 1.45 for the path from Mathematical Self-Efficacy to Critical Thinking and −0.69 for the path from Learning Motivation to Critical Thinking. A standardized coefficient exceeding 1.00 may indicate statistical issues such as multicollinearity, a suppression effect, excessively high correlations among predictors, or an improper estimation solution, including the possibility of a Heywood case. Therefore, before drawing substantive conclusions, it is important to examine the correlation between learning motivation and mathematical self-efficacy, the associated standard errors, the covariance matrix, and other diagnostic information provided by LISREL. Without these additional evaluations, the magnitude of the positive effect of self-efficacy and the negative effect of learning motivation may be overinterpreted.

Commented [28]: Please cross-check this sentence against the coefficient displayed in Figure 4, as the negative path value shown in the figure appears to differ from −0.69. All figures, tables, and narrative results should report identical values.

Commented [29]: I appreciate that the manuscript recognises this issue. Please complete the diagnostic check rather than leaving it only as a caution. At minimum, report the predictor correlation, variance inflation factors or equivalent diagnostics, standard errors, and whether any negative error variance or other improper estimate occurred.

The refinement of the structural model improved its overall fit by allowing correlations among several measurement errors based on the diagnostic information generated by LISREL. Statistically, this procedure substantially improved the model's goodness-of-fit indices. However, correlated error terms should be introduced only when supported by substantive theoretical justification rather than solely to improve model fit. Within the learning motivation construct, correlated errors may arise because certain questionnaire items share similar wording, contexts, or response patterns. Likewise, correlated errors among the critical thinking indicators may occur because several dimensions were assessed using related mathematical tasks or common problem-solving processes, resulting in shared variance that is not fully explained by the general latent construct.

Overall, the model refinement did not alter the underlying theoretical assumption that both learning motivation and mathematical self-efficacy are associated with students' critical thinking skills. Instead, it suggests that the relationships among the observed indicators are more complex than initially assumed, particularly when the independence of measurement errors is relaxed. Although the refined model demonstrates a substantially better fit to the empirical data, the RMSEA value of 0.093 indicates that some degree of model misfit remains. Accordingly, the final model is more appropriately described as exhibiting an acceptable (or marginal) fit rather than an excellent or close fit.

Theoretical and Educational Implications

The primary theoretical contribution of this study lies in distinguishing the roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills. Although both constructs represent important affective dimensions of learning, they operate through different psychological mechanisms. Learning motivation explains why students are willing to participate in learning activities, whereas mathematical self-efficacy explains whether students believe they possess the capability to perform the cognitive tasks required. In the context of mathematical critical thinking, this operational belief appears to be more directly associated with analyzing information, selecting appropriate strategies, drawing logical conclusions, and sustaining effort throughout complex problem-solving processes. From a pedagogical perspective, these findings suggest that mathematics instruction should extend beyond making learning activities interesting or personally relevant. Teachers should intentionally foster students' mathematical self-efficacy by providing challenging yet attainable tasks, offering graduated instructional support, delivering strategy-oriented feedback, incorporating peer modeling, and creating opportunities for students to learn

from and correct their mistakes. Contextual and problem-based learning approaches can effectively support these objectives, provided that the complexity of mathematical tasks is carefully calibrated to ensure that students experience genuine mastery rather than repeated failure. Previous studies have similarly shown that contextual and problem-based learning simultaneously promotes critical thinking and strengthens students' mathematical self-efficacy (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024b).

Particular attention should also be given to the relatively weaker dimensions of critical thinking identified in this study, namely elementary clarification and strategy and reflection. Teachers can strengthen these dimensions by routinely encouraging students to ask reflective questions such as: What information is provided? What is actually being asked? Why is this strategy appropriate? Are there alternative approaches? How can the correctness of the solution be verified? Such reflective practices are likely to strengthen the relationship between students' self-efficacy and the quality of their mathematical reasoning, ensuring that confidence is accompanied by genuine conceptual understanding and effective problem-solving competence.

Overall, the findings of this study indicate that mathematical self-efficacy represents the affective factor most directly associated with students' critical thinking skills. Although learning motivation remains an essential component of successful learning, its influence should be understood within a broader psychological framework in which its effects may operate through mathematical self-efficacy, self-regulated learning, persistence, and cognitive engagement during problem solving. Consequently, fostering students' critical thinking requires instructional approaches that simultaneously cultivate the desire to learn, strengthen confidence in mathematical competence, and develop habits of reflective and analytical thinking.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently.

Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self-efficacy. Teachers are encouraged to design learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the research involved a relatively small sample of 34 eighth-grade students from a single junior high school, limiting the generalizability of the findings to broader educational contexts. Second, the study focused exclusively on the Pythagorean theorem, meaning that the structural relationships identified may differ when applied to other mathematical topics with different cognitive characteristics. Third, the research adopted a cross-sectional design, which captures relationships among variables at a single point in time and therefore does not explain how learning motivation, mathematical self-efficacy, and critical thinking develop longitudinally. Finally, although the reanalyzed SEM model achieved acceptable goodness-of-fit indices, the RMSEA value (0.093) indicates that there is still room for improving the structural model by considering additional variables or alternative model specifications.

Suggestions

Future research is recommended to involve larger and more diverse samples from different schools and educational levels to improve the generalizability of the findings. Longitudinal or experimental studies are also needed to examine the causal development of critical thinking and to evaluate how instructional interventions enhance mathematical self-efficacy over time. In addition, future studies should incorporate other psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, problem-solving strategies, or classroom learning environment, to obtain a more comprehensive explanation of students' critical thinking skills.

From a practical perspective, mathematics teachers are encouraged to prioritize instructional strategies that strengthen students' mathematical self-efficacy through meaningful problem-solving experiences, guided practice, reflective discussion, and constructive feedback. Rather than merely increasing students' motivation to learn, instructional practices should cultivate confidence in applying mathematical knowledge, as this study indicates that mathematical self-efficacy is the affective factor most directly associated with students' critical thinking skills.

Conclusion

This study investigated the structural relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using Structural Equation Modeling (SEM). The measurement model demonstrated satisfactory psychometric properties, as evidenced by adequate sampling adequacy, acceptable construct validity, and high construct reliability. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data.

Commented [30]: Please qualify this conclusion until reliability and AVE are reported separately for each construct and the three-factor measurement structure is clarified. A more cautious wording would be appropriate given the sample size and model modifications.

The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence, analytical reasoning, and reflective thinking when confronting complex mathematical tasks.

The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

References

Agusman, Purwanto, & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the Relationship between Academic Self-motivation and the Mathematical Thinking: A Case Study of Secondary School Students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101334

Aulia, H. D., Umbara, D., Jupri, A., & Dahlan, J. A. (2025). Mathematical Critical Thinking Ability of Grade IX Students in Solving Ill-Structured Problems. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1), 185–194. https://doi.org/10.30998/formatif.v15i1.27337

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the Impact of Discovery Learning and Self-Efficacy on Students' Critical Thinking Skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4).

https://doi.org/10.35445/alishlah.v17i4.7134
Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122.
Bandura, A. (2014). Exercise of personal agency through the self-efficacy mechanism. In *Self-efficacy* (pp. 3–38). Taylor & Francis.
Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807
Cahyani, V. F., & Setyaningsih, R. (2024). The Implementation of Problem-Based Learning to Enhance Critical Thinking Skills in Solving Contextual Mathematics Problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29
Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement Model and Adaptation of Self-Efficacy toward Mathematics Reasoning among University Students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114
Farah Deeba, Sana Hafeez, Shazia Noureen. (2021). AN INVESTIGATION OF 10th GRADE STUDENTS' SELF-EFFICACY BELIEFS IN MATHEMATICS. *Pakistan Journal of Educational Research*, *4*(1). https://doi.org/10.52337/pjer.v4i1.145
Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007
Holenstein, M., Bruckmaier, G., & Grob, A. (2022). How do self-efficacy and self-concept impact mathematical achievement? The case of mathematical modelling. *British Journal of Educational Psychology*, *92*(1), e12443.
In'am, A., & Sutrisno, E. S. (2021). Strengthening Students' Self-Efficacy and Motivation in Learning Mathematics through the Cooperative Learning Model. *International Journal of Instruction*, *14*(1), 395–410.
Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2394738
Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140
Marlena, L., & Nugraheni, E. A. (2026). The Correlation Between Self-Efficacy and Critical Thinking Skills of Senior High School Students on the Pythagorean Theorem Material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587
Masitoh, L. F., & Fitriyani, H. (2018). Improving students' mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30.
Mawaddah, S., Syahri, M., & Soenaryo, S. F. (2026). The Application of Guided Inquiry to Students' Critical Thinking Skills in Pancasila Education Subjects with Self-Efficacy As a Moderator Variable. *Scaffolding: Jurnal Pendidikan Islam Dan Multikulturalisme*, *8*(1), 225–244. https://doi.org/10.37680/scaffolding.v8i1.8520
Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-Efficacy, Reflective Thinking, and Critical Thinking: A Structural Equation Modeling Study Among Adolescents. *Islamic Guidance and Counseling Journal*, *8*(2). https://doi.org/10.25217/0020258684000
Pajares, F., & Miller, M. D. (1995). Mathematics Self-Efficacy and Mathematics Performances: The Need for Specificity of Assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022-0167.42.2.190
Paudel, K. C., & Ghimire, S. P. (2024). Mathematics Self-efficacy among Secondary Level Students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130.
Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievementA multilevel analysis of the Programme for International Student Assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014
Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' Mathematical Creative Thinking and Learning Obstacles in Solving Ill-Structured Exponential Problems. *Jurnal Didaktik Matematika*, *12*(1),

53–74. https://doi.org/10.24815/jdm.v12i1.43834
Schunk, D. H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist*, *19*(1), 48–58.
Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033
Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of mathematics self-efficacy and motivation in mathematics performance across ethnicity. *The Journal of Educational Research*, *97*(4), 208–222.
Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? *Psychology, Evaluation, and Technology in Educational Research*, *7*(2), 292–302. https://doi.org/10.33292/petier.v7i2.304
Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How Students' Self-Efficacy Can Affect Their Mathematical Critical Thinking Ability? *(Jiml) Journal of Innovative Mathematics Learning*, *8*(3), 381–387. https://doi.org/10.22460/jiml.v8i3.26650
Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11*. https://doi.org/10.3389/feduc.2026.1696182
Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 1–29. https://doi.org/10.1186/s40536-024-00204-z
Yousuf, M. I., & Rajeswari, G. (2024). Relationship between Mathematics Self Efficacy and Mathematics Achievement. *International Journal of Emerging Knowledge Studies*, *03*(10), 797–802. https://doi.org/10.70333/ijeks-03-10-011
Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987
Yulianto, D., Umami, M. R., & Mony, R. S. (2024a). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900
Yulianto, D., Umami, M. R., & Mony, R. S. (2024b). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900
Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012023
Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.986622
Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

Journal of Advanced Sciences and Mathematics Education
Volume X, Issue X, xx -xx.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index

Mathematical Self-Efficacy Outweighs Learning Motivation in Predicting Students' Critical Thinking Skills

Article Info

Article history:

Received: Month XX, 20XX
Revised: Month XX, 20XX
Accepted: Month XX, 20XX
(Cambria 9)

Keywords:

Critical Thinking Skills
Motivation to Learn
Maths Self-Efficacy

Abstract

ABSTRACT
Background of study: Critical thinking is an essential competency that enables students to analyse information, justify strategies, draw logical conclusions, and reflect on solutions when solving mathematical problems. Its development is influenced not only by cognitive mastery but also by affective factors, particularly learning motivation and mathematical self-efficacy. Although both constructs are frequently associated with mathematical performance, their relative contributions to students' critical thinking remain insufficiently explained.
Aims and scope of paper: This study aims to examine the structural relationships between learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving mathematical problems related to the Pythagorean theorem. It also compares the relative effects of learning motivation and mathematical self-efficacy on critical thinking.
Methods: A quantitative cross-sectional correlational design was employed. The population comprised 76 eighth-grade students at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Indonesia. A total of 34 students, consisting of 17 males and 17 females, were selected through simple random sampling. Data were collected using a learning motivation questionnaire based on the ARCS model, a mathematical self-efficacy questionnaire covering level, strength, and generality, and a critical thinking test based on Ennis' indicators. The data were analysed using Confirmatory Factor Analysis and Structural Equation Modeling with LISREL 8.80.
Result: The KMO value of 0.892 and a significant Bartlett's Test confirmed the suitability of the data for factor analysis. All indicators had factor loadings above 0.50 and significantly represented their respective constructs. Following model reanalysis, the structural model achieved acceptable fit, with NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, and RMSEA = 0.093. Mathematical self-efficacy had a positive and significant effect on critical thinking (t = 4.40), whereas learning motivation showed a significant negative relationship (t = −2.26).
Conclusion: Mathematical self-efficacy plays a more proximal and dominant role in supporting students' critical thinking than learning motivation. Students' confidence and persistence in performing mathematical tasks appear to be more directly connected to critical reasoning than their general willingness to learn.

To cite this article: Author. (20XX). Title. *Journal of Advanced Sciences and Mathematics Education, X*(X), XX-XX

INTRODUCTION

Critical thinking has become an essential competence in mathematics education because students are expected not only to obtain correct answers but also to examine information, justify strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Aulia et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). In such situations, students must understand the problem, identify relevant information, connect mathematical concepts, compare alternative strategies, and reflect on the reasonableness of their solutions. Nevertheless, many students still experience difficulties in analysing mathematical problems, explaining the basis of their answers, and selecting appropriate problem-solving strategies. These conditions indicate that the development of critical thinking remains an important challenge in secondary mathematics education.

Students' critical thinking performance is influenced not only by cognitive knowledge but also by affective factors that shape how they approach challenging tasks. Two factors frequently associated with mathematical learning are learning motivation and mathematical self-efficacy. Learning

Commented [1]: The title is memorable, but it sounds more conclusive than the study design allows. Because the analysis is cross-sectional and context-specific, please consider a title that emphasises comparison rather than superiority.

Commented [2]: The manuscript mixes British and American English. Please select one variety and use it consistently. If British English is retained, consider "analysed" and "modelling"; if American English is retained, use "analyze" and "memorized."

Commented [3]: "Aims and scope of paper" sounds somewhat unusual for an empirical abstract. "Purpose" or "Objective" would be more natural unless this wording is strictly required by the journal template.

Commented [5]: Please align the keywords with the terminology used in the title and main text. "Learning motivation" and "mathematical self-efficacy" would be more consistent than "Motivation to Learn" and "Maths Self-Efficacy."

Commented [4]: Please change "Result" to "Results," as the paragraph reports several findings rather than a single result.

Commented [6]: This is an important problem statement, but it currently appears as a broad assertion. Please provide evidence from previous empirical studies, national assessments, or the local educational context to support it.

motivation encourages students to participate, persist, and direct their efforts towards learning goals. Motivated students are generally expected to show greater attention, perseverance, and willingness to solve difficult problems. However, empirical evidence concerning the relationship between motivation and mathematical thinking has not always been consistent. Alotaibi, for example, found that academic self-motivation showed limited or no dependence on the mathematical thinking of secondary school students (Alotaibi, 2020). This finding suggests that students' willingness to learn may not automatically translate into the ability to analyse, evaluate, and solve mathematical problems critically.

Mathematical self-efficacy refers to students' beliefs about their capacity to perform mathematical tasks successfully (Chan et al., 2022; Farah Deeba, Sana Hafeez, Shazia Noureen, 2021; Pajares & Miller, 1995; et al., 2024; Yuliyanto et al., 2021; Zakariya, 2022). Unlike general interest or willingness to learn, self-efficacy is closely related to students' judgments about whether they can organise and carry out the actions required to solve a particular problem. Students with strong self-efficacy are more likely to attempt challenging questions, maintain effort after experiencing difficulty, test alternative strategies, and interpret mistakes as part of the learning process. Conversely, students who doubt their mathematical capabilities may avoid complex tasks, rely excessively on procedural routines, or abandon problem-solving efforts prematurely. Recent research shows that mathematics self-efficacy among secondary students varies across groups and educational levels, emphasising the need for systematic support to strengthen students' confidence in learning mathematics (Paudel & Ghimire, 2024).

Previous studies have provided evidence of a positive relationship between self-efficacy and mathematical critical thinking. Yulianto et al. reported that self-efficacy contributed significantly to students' critical mathematical thinking and interacted with the instructional approach used in mathematics classrooms (Yulianto et al., 2024a). Similarly, Marlena and Nugraheni found a strong positive correlation between self-efficacy and critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). These findings indicate that students' confidence in their mathematical capabilities may serve as an important affective foundation for engaging in complex reasoning. However, much of the existing research has examined self-efficacy in relation to critical thinking as a single association, compared critical thinking across self-efficacy levels, or investigated self-efficacy within particular instructional interventions.

This leaves several important gaps. First, motivation and mathematical self-efficacy are often studied separately, even though both constructs may operate simultaneously when students confront difficult mathematical problems. Consequently, the relative contribution of each construct to critical thinking is not yet sufficiently explained. Second, correlational evidence showing that motivation or self-efficacy is associated with critical thinking does not necessarily clarify whether each variable retains a meaningful contribution when both are included in the same model. Third, existing studies commonly assume that high learning motivation naturally supports higher-order thinking, while giving less attention to the possibility that motivation may be related to critical thinking at the bivariate level but lose its explanatory power after mathematical self-efficacy is considered. Fourth, studies focusing specifically on students' critical thinking when solving Pythagorean problems remain limited, even though this topic requires students to interpret problem situations, determine relevant relationships, select strategies, and justify mathematical conclusions.

Accordingly, the novelty of this study lies in examining learning motivation and mathematical self-efficacy simultaneously and comparing their relative roles as predictors of students' critical thinking skills. Rather than merely determining whether both affective variables correlate with critical thinking, this study investigates which construct provides the stronger direct contribution when the variables are analysed within the same structural model. This comparative perspective is important because students may possess a strong desire to learn but still hesitate when they do not believe that they can complete a mathematical task successfully. Thus, the study distinguishes between students' willingness to engage in learning and their confidence in performing the cognitive actions required for critical problem solving.

This study therefore aims to analyse the direct and simultaneous effects of learning motivation and mathematical self-efficacy on students' critical thinking skills in solving mathematics problems. Specifically, it addresses three questions: whether learning motivation significantly predicts students' critical thinking skills, whether mathematical self-efficacy significantly predicts students'

Commented [7]: This citation contains two formatting problems: the authors "Farah Deeba, Sana Hafeez, Shazia Noureen" are not presented in standard author-date format, and "et al., 2024" has no lead author. Please correct the citation and check it against the reference list.

Commented [8]: The gap is clearly organised, but several claims would benefit from direct supporting citations. Please show which prior studies examined the variables separately and which studies failed to compare their unique contributions in the same model.

Commented [9]: Please explain more clearly why the Pythagorean theorem is theoretically valuable for studying critical thinking. Is it selected because it requires representation, proof, strategy selection, transfer across contexts, or non-routine reasoning?

Commented [10]: The contribution is useful, although "novelty" may be slightly overstated because simultaneous-predictor models are not uncommon. It may be more convincing to frame this as the study's "specific contribution," particularly in the Pythagorean problem-solving context.

critical thinking skills, and how strongly the two variables jointly explain variations in critical thinking. By clarifying their relative contributions, the findings are expected to provide a more precise basis for designing mathematics instruction that not only stimulates students' interest and persistence but also strengthens their confidence in analysing, reasoning, and solving challenging mathematical problems.

Commented [11]: Please present these as numbered research questions or explicit hypotheses. This would make it easier to connect each question with a specific result and conclusion.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Commented [12]: Please add a little more explanation of how Bandura's theory connects motivation, self-efficacy, and critical thinking. At present, the model is named but not conceptually derived in enough detail.

Participants

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected through simple random sampling to ensure that every student had an equal probability of participation.

Prior to data collection, students and the school administration were informed about the objectives of the study, and participation was voluntary. All collected data were treated confidentially and used solely for research purposes.

Instruments

Three research instruments were employed.

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, consisting of four dimensions: Attention, Relevance, Confidence, and Satisfaction. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework. The instrument measured three dimensions:

a. Level
b. Strength
c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks with varying levels of complexity.

Commented [13]: Please clarify whether the items referred specifically to Pythagorean tasks or to mathematics in general. This distinction is important because self-efficacy measures are usually most informative when closely matched to the target performance domain.

Critical Thinking Test

Students' critical thinking skills were measured using essay-type mathematical problems developed within the Pythagorean Theorem context. The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:

a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

All instruments underwent expert judgment by mathematics education specialists prior to implementation to establish content validity.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Commented [14]: Please report the duration of the test and whether the same teacher, instructions, and testing conditions were used for all students. This information would make the procedure more reproducible.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, several statistical assumptions were evaluated, including normality, linearity, homogeneity, and multicollinearity.

he measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50.

Commented [15]: Please correct the missing initial letter to "The." A final proofreading pass is also needed for spacing, broken symbols, hyphenation, and words split across lines.

The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual (SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values.

Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 (α = 0.05). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

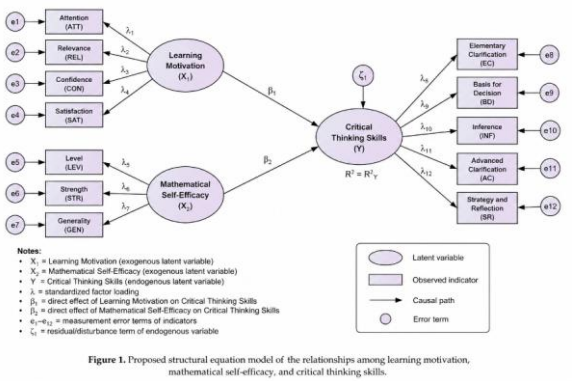


Figure 1. Proposed structural equation model of the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills.

RESULTS AND DISCUSSION

RESULTS

Preliminary Analysis

Descriptive Statistics

Commented [16]: No means, standard deviations, distributions, or score ranges are presented under this heading. Please provide the descriptive results or use a heading that more accurately reflects the content, such as "Preliminary Measurement Analysis."

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were

appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis.

The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test	Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result ($\chi^2 = 1307.307$, $df = 66$, $p < 0.001$), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis.

Overall, the results of the KMO measure and Bartlett's Test provide empirical evidence that the dataset satisfies the fundamental assumptions for conducting Confirmatory Factor Analysis (CFA). Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL.

Commented [17]: The KMO and Bartlett procedures are explained several times. Please condense this discussion and devote more space to the substantive results, particularly the correlations, path coefficients, and explained variance.

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model.

Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

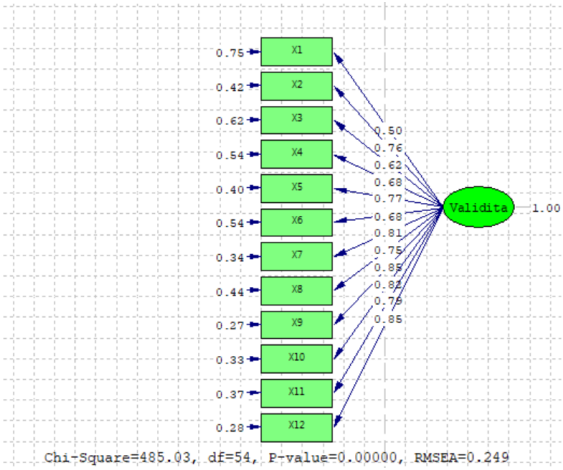


Figure 2. Uji CFA

Commented [18]: Please translate this caption fully into English and describe what is displayed, for example, "Figure 2. Initial confirmatory factor analysis model."

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor dan Error Variance

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Commented [19]: Decimal commas and decimal points are used inconsistently. An English-language journal normally requires decimal points throughout. Please standardise all statistical values in the text, tables, and figures.

Construct Reliability (CR)
Using the Fornell & Larcker (1981) formula:

$$CR = \frac{(\sum\lambda)^2}{(\sum\lambda)^2 + \sum\varepsilon}$$

Calculation results:

$$\sum\lambda = 8{,}58$$
$$(\sum\lambda)^2 = 73{,}62$$
$$\sum\varepsilon = 5{,}30$$

so that

$$CR = \frac{73{,}62}{73{,}62 + 5{,}30} = 0{,}933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.

Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum \lambda^2}{n}$$

Sum of squared loadings

$$\sum \lambda^2 = 6{,}70$$

with

$$n = 12$$

so

$$AVE = \frac{6{,}70}{12} = 0{,}558$$

AVE = 0,558
The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity.

In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). The results indicated a Construct Reliability (CR) value of 0.933, which is well above the recommended minimum threshold of 0.70. This finding demonstrates that the indicators exhibit excellent internal consistency in measuring the latent constructs investigated in this study.
Furthermore, the Average Variance Extracted (AVE) value of 0.558 indicates that more than 55% of the variance in the observed indicators is explained by their corresponding latent constructs. Since this value exceeds the recommended criterion of 0.50, the constructs demonstrate satisfactory convergent validity. These findings indicate that the observed indicators are not only valid based on their standardized factor loadings but also consistently represent the latent constructs they were designed to measure.
Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Structural Model Evaluation
After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data.
The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI

= 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, model reanalysis was conducted based on the diagnostic information provided by LISREL. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. All goodness-of-fit indices satisfied the recommended criteria, with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement.

The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

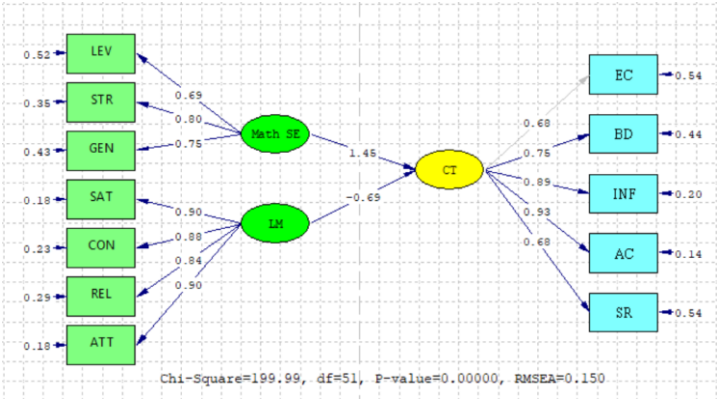


Figure 3. Model SEM

Tabel 3. Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,88	Not Good
2	GFI	≥ 90	0.88	Not Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good
5	RMSEA	≥ 0.08	0,150	Good

Commented [20]: The figures are difficult to read because the labels and coefficients are small and the screenshots include considerable unused background. Please recreate or export the diagrams at higher resolution with consistent English labels and readable coefficients.

Commented [21]: Please translate all table headings into English. "Analysis Results" would be clearer, although the table could be simplified to "Index," "Recommended criterion," "Obtained value," and "Interpretation."

Commented [22]: Please revise this to "Cut-off Value" or, preferably, "Recommended Criterion." The column is currently empty, so the relevant thresholds should also be inserted.

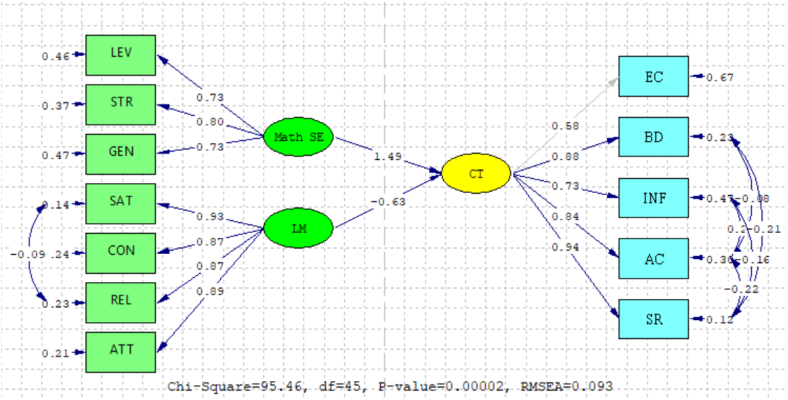


Figure 4. Reanalisis Model SEM

Tabel 4. Reanalisis Goodness-of-Fit model

No	Goodness of Fit	Hasil Analisis		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,97	Good
2	CFI	≥ 90	0.98	Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≤ 0.08	0,093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero.

As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value (|−2.26| = 2.26) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction.

These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the proposed structural relationships were empirically supported based on the significance of the estimated t-values.

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level.

As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Regarding the structural relationships, the path from Mathematical Self-Efficacy to Critical Thinking yielded a t-value of 4.40, indicating a positive and statistically significant effect. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold (|−2.26| > 1.96), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy.

Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

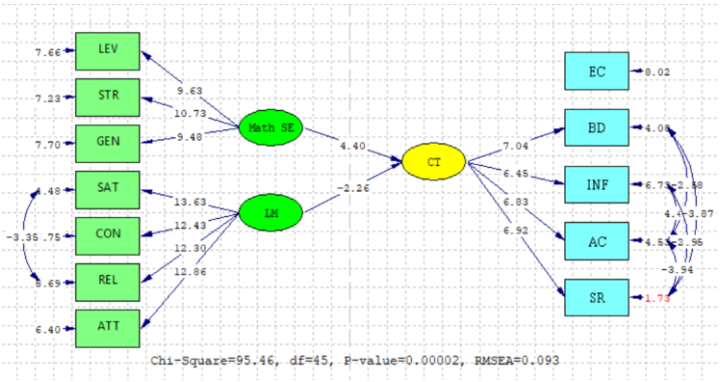


Figure 5. t-value Model SEM

DISCUSSION

The findings of this study indicate that students' critical thinking skills are determined not only by their mastery of mathematical concepts but also by their beliefs and internal drives when confronting mathematical problems. The proposed structural model identifies learning motivation and mathematical self-efficacy as two affective factors that explain students' ability to clarify problems, use evidence as a basis for judgment, draw inferences, provide further explanations, and determine appropriate problem-solving strategies. Following model refinement, the structural model demonstrated a substantially improved fit to the empirical data, as reflected by NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94. In addition, the reduction in RMSEA from 0.150 to 0.093 indicates that the discrepancy between the theoretical model and the observed data was considerably reduced.

Commented [23]: "Are determined" is too causal for the design. Please use "are associated with" or "may be related to." The study did not measure mathematical concept mastery directly, so that part of the sentence should also be reconsidered.

Although the RMSEA value remains above the threshold for a close fit, it falls within the range generally considered to represent an acceptable or marginal model fit, thereby supporting the use of the revised model for hypothesis testing.

Structure of the Learning Motivation Construct

The construct of learning motivation was represented by four indicators: attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. These values indicate that all four indicators provide strong representations of students' learning motivation. Among them, attention and satisfaction exhibited the highest factor loadings (0.90), suggesting that students' motivation is primarily reflected in their ability to maintain attention during learning activities and in the satisfaction they experience after completing mathematical tasks or participating in classroom learning.

The prominence of the attention indicator suggests that students' initial engagement plays a fundamental role in sustaining learning motivation. Students who are able to focus their attention tend to be more receptive to new information, actively participate in problem-solving processes, and remain engaged throughout learning activities. Likewise, the strong contribution of satisfaction indicates that experiences of success, recognition, and perceived learning benefits reinforce students' motivation. These findings imply that learning motivation is not merely an antecedent of learning but is continuously strengthened through positive learning experiences and successful task completion.

The confidence indicator produced a standardized loading factor of 0.88. Although confidence is conceptualized as one of the four dimensions of the ARCS motivational model, it differs conceptually from mathematical self-efficacy, which constitutes a separate latent construct in this study. Within the ARCS framework, confidence reflects students' general expectations of success during the learning process, whereas mathematical self-efficacy refers to students' beliefs about their capability to perform specific mathematical tasks successfully. This conceptual proximity should be carefully considered because it may generate empirical overlap between learning motivation and mathematical self-efficacy. Such overlap provides a plausible explanation for why the structural path from learning motivation to critical thinking became negative when both constructs were estimated simultaneously within the same structural model.

The present findings are consistent with the study conducted by In'am and Sutrisno, who reported that the Teams Games Tournament (TGT) cooperative learning model enhanced both students' learning motivation and mathematical self-efficacy through intensive peer interaction and shared experiences of success (In'am & Sutrisno, 2021). Their findings also suggest that learning motivation and self-efficacy tend to develop simultaneously during instructional activities, making the two constructs difficult to distinguish empirically. Consequently, when both variables are incorporated into a single structural equation model, a degree of conceptual and statistical overlap may occur, potentially influencing the direction and magnitude of the estimated structural coefficients.

Struktur konstruk self-efficacy matematis

Mathematical self-efficacy was measured using three indicators: level, strength, and generality, with standardized factor loadings of 0.69, 0.80, and 0.75, respectively. Among these dimensions, strength emerged as the strongest indicator of mathematical self-efficacy. This finding suggests that students' self-efficacy is primarily reflected in the strength of their belief that they can persist when confronted with mathematical challenges, rather than merely in their willingness to undertake tasks of varying levels of difficulty.

The dominance of the strength dimension has important implications for the development of critical thinking skills. Solving mathematical problems that require critical thinking rarely leads to immediate solutions. Instead, students are often required to test alternative strategies, identify and correct errors, revise their approaches, and continuously evaluate the appropriateness of their solutions. Under such circumstances, the strength of students' self-beliefs determines whether they remain engaged in the problem-solving process or abandon their efforts after encountering initial failure. Therefore, mathematical self-efficacy should be viewed not simply as a positive perception of one's own abilities, but as a psychological resource that sustains persistence and supports higher-order cognitive processes during complex mathematical reasoning.

Commented [24]: A higher factor loading shows a stronger relationship between an indicator and the latent construct, but it does not necessarily show that students possessed more attention or satisfaction. Please keep the interpretation at the measurement level.

Commented [25]: This heading remains in Indonesian. Please translate it to "Structure of the Mathematical Self-Efficacy Construct" and check the whole manuscript for other untranslated terms.

Commented [26]: This is acceptable as a measurement statement, but the following interpretation becomes rather broad. Please avoid treating the strongest loading as proof that persistence is the most important psychological mechanism unless the study directly tested that mechanism.

The generality dimension, with a standardized loading of 0.75, indicates that students with higher mathematical self-efficacy tend to transfer their confidence across different mathematical contexts. In contrast, the level dimension exhibited the lowest loading (0.69), suggesting that students' confidence in dealing with progressively more difficult mathematical tasks is relatively weaker than their determination to persist. In other words, students may remain motivated to continue working on mathematical problems, yet their confidence may decline as the complexity of the tasks increases substantially.

These findings are consistent with the study by Yulianto, Umami, and Mony, who reported that mathematical self-efficacy makes a significant contribution to students' critical thinking skills. Their study further demonstrated that the influence of self-efficacy is moderated by the instructional approach adopted in the classroom, highlighting the interaction between affective and pedagogical factors in promoting higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Mawaddah et al., 2026; Sudiartini et al., 2025). Similarly, Yang, Maeda, and Gentry, using data from the National Assessment of Educational Progress (NAEP), identified mathematical self-efficacy as a robust predictor of mathematics achievement across different grade levels, even after controlling for student- and school-level characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these studies support the view that mathematical self-efficacy represents a proximal psychological factor that directly influences students' cognitive engagement and their capacity to think critically when solving mathematical problems.

Structure of the Critical Thinking Construct

The construct of critical thinking was represented by five indicators: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The standardized factor loadings ranged from 0.68 to 0.93, indicating that all indicators made meaningful contributions to the latent construct. Among these dimensions, advanced clarification exhibited the highest loading (0.93), followed by inference (0.89). These findings suggest that students' critical thinking skills are most strongly reflected in their ability to provide well-reasoned explanations and to draw logical conclusions based on the information available and the problem-solving processes they employ.

The prominence of advanced clarification indicates that critical thinking extends beyond simply obtaining correct answers. Rather, it is demonstrated through students' ability to justify the strategies they select, establish logical connections among relevant information, identify underlying assumptions, and clarify the reasoning that supports their conclusions. In mathematics education, this dimension is particularly important because a correct numerical answer does not necessarily reflect a deep conceptual understanding. Students may arrive at the correct solution by applying memorized procedures, yet still be unable to explain why those procedures are appropriate or mathematically justified. Therefore, encouraging students to articulate their reasoning is an essential component of fostering higher-order thinking.

The strong loading of the inference dimension further highlights that drawing logical conclusions constitutes a central component of critical thinking within the proposed model. Students are expected not only to perform mathematical calculations but also to interpret the results, evaluate the available evidence, and formulate conclusions that are logically coherent and mathematically defensible. This finding suggests that critical thinking progresses from understanding and processing information toward constructing reasoned judgments supported by evidence.

In contrast, elementary clarification and strategy and reflection exhibited the lowest standardized loadings (0.68 each). Although both indicators remained statistically significant and met the acceptable validity criteria, their relatively lower contributions suggest that students are less proficient in identifying the core elements of a problem and critically evaluating their own solution strategies than they are in explaining reasoning and drawing inferences. The comparatively weaker contribution of strategy and reflection may indicate that many students tend to stop once they obtain an answer, without verifying the accuracy of their reasoning, considering alternative solution strategies, or reflecting on the efficiency and appropriateness of their problem-solving process. Such tendencies may limit the development of deeper metacognitive skills that are fundamental to effective mathematical reasoning.

These findings have important implications for mathematics instruction. Developing students' critical thinking skills requires more than presenting increasingly difficult mathematical problems.

Commented [27]: The loading does not demonstrate actual transfer across contexts. It only indicates how strongly the generality indicator relates to the latent construct. Please revise this interpretation unless cross-context transfer was directly measured.

Commented [28]: Some cited studies appear to come from science or Pancasila education rather than mathematics. These sources may still be useful, but please explain their conceptual relevance and give greater emphasis to directly comparable mathematics-education studies.

Commented [29]: Lower factor loadings do not indicate lower student proficiency. Proficiency should be inferred from means, score distributions, or item-level performance, not from measurement loadings. Please revise this paragraph accordingly.

Teachers should create learning environments that encourage students to identify relevant information, clarify problem requirements, compare alternative solution strategies, justify their reasoning, and critically evaluate the validity and efficiency of their solutions. Contextual and problem-based learning effectively promotes critical thinking by providing students with meaningful opportunities to analyze real-world situations, select appropriate strategies, justify their reasoning, and reflect on the quality of their solutions (Anggraeni et al., 2023; Yu & Zin, 2023). Such instructional approaches not only improve mathematical performance but also cultivate the reflective and analytical thinking processes that characterize effective critical thinkers.

The Effect of Mathematical Self-Efficacy on Critical Thinking Skills

The structural analysis indicates that mathematical self-efficacy has a positive and significant effect on critical thinking skills, with a T-value of 4.40. These findings confirm that students' belief in their ability to solve math problems plays a significant role in supporting higher-order thinking activities. Students with strong self-efficacy tend to be better prepared to tackle non-routine problems, persevere when encountering obstacles, and use mistakes as a basis for refining their strategies.

This influence can be explained by the close relationship between self-efficacy and the task-solving process. Critical thinking requires sustained cognitive engagement, while self-efficacy determines the extent to which students are willing to activate and maintain that engagement. When students are confident in their ability to solve problems, their cognitive resources are more likely to be directed toward problem analysis rather than toward anxiety, doubt, or the desire to avoid the task. Self-efficacy makes a significant contribution to mathematical critical thinking ability (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). These findings are also consistent with research showing that self-efficacy is a strong predictor of mathematics achievement from elementary through high school. Although mathematical achievement differs from critical thinking, both findings point to a similar mechanism: belief in one's own abilities supports the courage to make decisions, sustain effort, and manage difficulties in mathematical tasks.

Mathematical self-efficacy and mathematical thinking are the closest direct predictors of problem-solving ability. In their model, motivation functions as an upstream factor, while its influence on problem-solving is mediated through more proximal processes, particularly self-efficacy and mathematical thinking. These findings help explain the results of this study, which show that self-efficacy has a stronger direct influence on critical thinking than learning motivation.

Commented [30]: This sentence seems to refer to a previous model, but the source is not clearly identified. Please name and cite the study at the beginning of the sentence, or clarify that this is the authors' theoretical interpretation.

Commented [31]: This is an interesting explanation, but mediation was not tested in the present study. Please make it clear that this is a theoretical possibility drawn from previous research rather than an empirical finding of the current analysis.

Relationship Between Learning Motivation and Critical Thinking Skills

The structural path from Learning Motivation to Critical Thinking yielded a t-value of −2.26. Because the absolute value exceeds the critical threshold of 1.96, the relationship is statistically significant; however, the estimated effect is negative. This finding should not be interpreted as evidence that learning motivation inherently diminishes students' critical thinking skills. Rather, the negative coefficient should be understood within the context of the structural model, in which mathematical self-efficacy was simultaneously included as a predictor.

When examined independently, learning motivation is generally expected to be positively associated with students' engagement in learning activities. However, after controlling for the variance shared with mathematical self-efficacy, the unique contribution of learning motivation may exhibit a different relationship with critical thinking. This pattern may reflect a suppression effect or substantial conceptual overlap between the two constructs, particularly because the confidence dimension of the ARCS motivational model is conceptually related to mathematical self-efficacy. Consequently, the negative coefficient should not be interpreted as suggesting that attention, relevance, satisfaction, or the desire to learn are detrimental to critical thinking. Instead, it indicates that learning motivation, in the absence of strong beliefs about one's mathematical competence, may not necessarily translate into effective critical thinking performance.

Commented [32]: This is a plausible explanation, but it should be supported by the bivariate correlations, predictor correlation, and relevant diagnostics. Without these data, please present suppression as a tentative possibility rather than the main explanation.

Students may demonstrate high levels of attention, perceive mathematics as relevant, and possess a strong desire to achieve positive learning outcomes, yet still struggle when required to select appropriate problem-solving strategies, tolerate uncertainty, or justify mathematical reasoning. Under these circumstances, learning motivation provides the impetus to engage in learning, whereas mathematical self-efficacy determines whether this motivation can be transformed into effective cognitive action. Therefore, learning motivation can be viewed as the factor that initiates students'

engagement, while mathematical self-efficacy functions as the proximal operational belief that enables students to persist, regulate their efforts, and successfully perform complex mathematical tasks.

This interpretation is consistent with previous research suggesting that learning motivation functions as an upstream motivational predictor, whereas self-efficacy serves as a more proximal psychological mechanism underlying successful problem solving (Bandura, 1982, 2014; Schunk, 1984). Likewise, In'am and Sutrisno reported that cooperative learning experiences simultaneously enhance students' learning motivation and mathematical self-efficacy, indicating that the two constructs tend to develop together rather than independently (Holenstein et al., 2022; Stevens et al., 2004; Zimmerman, 2000). These findings imply that instructional interventions should extend beyond increasing students' interest in learning by providing authentic mastery experiences that transform motivation into confidence in mathematical competence.

Nevertheless, the negative structural coefficient should be interpreted with caution. The standardized structural model produced coefficients of 1.45 for the path from Mathematical Self-Efficacy to Critical Thinking and −0.69 for the path from Learning Motivation to Critical Thinking. A standardized coefficient exceeding 1.00 may indicate statistical issues such as multicollinearity, a suppression effect, excessively high correlations among predictors, or an improper estimation solution, including the possibility of a Heywood case. Therefore, before drawing substantive conclusions, it is important to examine the correlation between learning motivation and mathematical self-efficacy, the associated standard errors, the covariance matrix, and other diagnostic information provided by LISREL. Without these additional evaluations, the magnitude of the positive effect of self-efficacy and the negative effect of learning motivation may be overinterpreted.

The refinement of the structural model improved its overall fit by allowing correlations among several measurement errors based on the diagnostic information generated by LISREL. Statistically, this procedure substantially improved the model's goodness-of-fit indices. However, correlated error terms should be introduced only when supported by substantive theoretical justification rather than solely to improve model fit. Within the learning motivation construct, correlated errors may arise because certain questionnaire items share similar wording, contexts, or response patterns. Likewise, correlated errors among the critical thinking indicators may occur because several dimensions were assessed using related mathematical tasks or common problem-solving processes, resulting in shared variance that is not fully explained by the general latent construct.

Overall, the model refinement did not alter the underlying theoretical assumption that both learning motivation and mathematical self-efficacy are associated with students' critical thinking skills. Instead, it suggests that the relationships among the observed indicators are more complex than initially assumed, particularly when the independence of measurement errors is relaxed. Although the refined model demonstrates a substantially better fit to the empirical data, the RMSEA value of 0.093 indicates that some degree of model misfit remains. Accordingly, the final model is more appropriately described as exhibiting an acceptable (or marginal) fit rather than an excellent or close fit.

Theoretical and Educational Implications

The primary theoretical contribution of this study lies in distinguishing the roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills. Although both constructs represent important affective dimensions of learning, they operate through different psychological mechanisms. Learning motivation explains why students are willing to participate in learning activities, whereas mathematical self-efficacy explains whether students believe they possess the capability to perform the cognitive tasks required. In the context of mathematical critical thinking, this operational belief appears to be more directly associated with analyzing information, selecting appropriate strategies, drawing logical conclusions, and sustaining effort throughout complex problem-solving processes. From a pedagogical perspective, these findings suggest that mathematics instruction should extend beyond making learning activities interesting or personally relevant. Teachers should intentionally foster students' mathematical self-efficacy by providing challenging yet attainable tasks, offering graduated instructional support, delivering strategy-oriented feedback, incorporating peer modeling, and creating opportunities for students to learn

from and correct their mistakes. Contextual and problem-based learning approaches can effectively support these objectives, provided that the complexity of mathematical tasks is carefully calibrated to ensure that students experience genuine mastery rather than repeated failure. Previous studies have similarly shown that contextual and problem-based learning simultaneously promotes critical thinking and strengthens students' mathematical self-efficacy (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024b).

Particular attention should also be given to the relatively weaker dimensions of critical thinking identified in this study, namely elementary clarification and strategy and reflection. Teachers can strengthen these dimensions by routinely encouraging students to ask reflective questions such as: What information is provided? What is actually being asked? Why is this strategy appropriate? Are there alternative approaches? How can the correctness of the solution be verified? Such reflective practices are likely to strengthen the relationship between students' self-efficacy and the quality of their mathematical reasoning, ensuring that confidence is accompanied by genuine conceptual understanding and effective problem-solving competence.

Overall, the findings of this study indicate that mathematical self-efficacy represents the affective factor most directly associated with students' critical thinking skills. Although learning motivation remains an essential component of successful learning, its influence should be understood within a broader psychological framework in which its effects may operate through mathematical self-efficacy, self-regulated learning, persistence, and cognitive engagement during problem solving. Consequently, fostering students' critical thinking requires instructional approaches that simultaneously cultivate the desire to learn, strengthen confidence in mathematical competence, and develop habits of reflective and analytical thinking.

Commented [33]: This is a useful recommendation. Please connect each proposed strategy more explicitly to Bandura's sources of self-efficacy—mastery experiences, vicarious experiences, verbal persuasion, and emotional states—to strengthen the theoretical contribution.

Commented [34]: This message is repeated in the Discussion, Implications, Suggestions, and Conclusion. Please reduce repetition and use the additional space to explain the study's boundary conditions and the meaning of the unexpected negative motivation coefficient.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently.

Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self-efficacy. Teachers are encouraged to design learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the research involved a relatively small sample of 34 eighth-grade students from a single junior high school, limiting the generalizability of the findings to broader educational contexts. Second, the study focused exclusively on the Pythagorean theorem, meaning that the structural relationships identified may differ when applied to other mathematical topics with different cognitive characteristics. Third, the research adopted a cross-sectional design, which captures relationships among variables at a single point in time and therefore does not explain how learning motivation, mathematical self-efficacy, and critical thinking develop longitudinally. Finally, although the reanalyzed SEM model achieved acceptable goodness-of-fit indices, the RMSEA value (0.093) indicates that there is still room for improving the structural model by considering additional variables or alternative model specifications.

Commented [35]: The limitations section is helpful. Please also mention the use of self-report questionnaires, possible shared-method variance between the two affective constructs, conceptual overlap between ARCS confidence and mathematical self-efficacy, and the data-driven model modifications.

Suggestions

Future research is recommended to involve larger and more diverse samples from different schools and educational levels to improve the generalizability of the findings. Longitudinal or experimental studies are also needed to examine the causal development of critical thinking and to evaluate how instructional interventions enhance mathematical self-efficacy over time. In addition, future studies should incorporate other psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, problem-solving strategies, or classroom learning environment, to obtain a more comprehensive explanation of students' critical thinking skills.

From a practical perspective, mathematics teachers are encouraged to prioritize instructional strategies that strengthen students' mathematical self-efficacy through meaningful problem-solving experiences, guided practice, reflective discussion, and constructive feedback. Rather than merely increasing students' motivation to learn, instructional practices should cultivate confidence in applying mathematical knowledge, as this study indicates that mathematical self-efficacy is the affective factor most directly associated with students' critical thinking skills.

Conclusion

This study investigated the structural relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using Structural Equation Modeling (SEM). The measurement model demonstrated satisfactory psychometric properties, as evidenced by adequate sampling adequacy, acceptable construct validity, and high construct reliability. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data.

The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence, analytical reasoning, and reflective thinking when confronting complex mathematical tasks.

The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

Commented [36]: "Causal development" sounds somewhat awkward. Consider "to examine temporal ordering and provide stronger evidence regarding causal relationships."

Commented [37]: This is a reasonable summary, but please state that the negative motivation coefficient is conditional on the inclusion of self-efficacy and may be affected by predictor overlap. This qualification is essential to prevent readers from concluding that motivation is harmful.

Commented [38]: Please temper "should prioritize" because the study was observational and involved one small sample. "Suggest that educators may consider strengthening…" would be more proportionate to the evidence.

References

Agusman, Purwanto, & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the Relationship between Academic Self-motivation and the Mathematical Thinking: A Case Study of Secondary School Students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101334

Aulia, H. D., Umbara, D., Jupri, A., & Dahlan, J. A. (2025). Mathematical Critical Thinking Ability of Grade IX Students in Solving Ill-Structured Problems. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1), 185–194. https://doi.org/10.30998/formatif.v15i1.27337

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the Impact of Discovery Learning and Self-Efficacy on Students' Critical Thinking Skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4).

https://doi.org/10.35445/alishlah.v17i4.7134
Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122.
Bandura, A. (2014). Exercise of personal agency through the self-efficacy mechanism. In *Self-efficacy* (pp. 3–38). Taylor & Francis.
Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807
Cahyani, V. F., & Setyaningsih, R. (2024). The Implementation of Problem-Based Learning to Enhance Critical Thinking Skills in Solving Contextual Mathematics Problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29
Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement Model and Adaptation of Self-Efficacy toward Mathematics Reasoning among University Students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114
Farah Deeba, Sana Hafeez, Shazia Noureen. (2021). AN INVESTIGATION OF 10th GRADE STUDENTS' SELF-EFFICACY BELIEFS IN MATHEMATICS. *Pakistan Journal of Educational Research*, *4*(1). https://doi.org/10.52337/pjer.v4i1.145
Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007
Holenstein, M., Bruckmaier, G., & Grob, A. (2022). How do self-efficacy and self-concept impact mathematical achievement? The case of mathematical modelling. *British Journal of Educational Psychology*, *92*(1), e12443.
In'am, A., & Sutrisno, E. S. (2021). Strengthening Students' Self-Efficacy and Motivation in Learning Mathematics through the Cooperative Learning Model. *International Journal of Instruction*, *14*(1), 395–410.
Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2394738
Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140
Marlena, L., & Nugraheni, E. A. (2026). The Correlation Between Self-Efficacy and Critical Thinking Skills of Senior High School Students on the Pythagorean Theorem Material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587
Masitoh, L. F., & Fitriyani, H. (2018). Improving students' mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30.
Mawaddah, S., Syahri, M., & Soenaryo, S. F. (2026). The Application of Guided Inquiry to Students' Critical Thinking Skills in Pancasila Education Subjects with Self-Efficacy As a Moderator Variable. *Scaffolding: Jurnal Pendidikan Islam Dan Multikulturalisme*, *8*(1), 225–244. https://doi.org/10.37680/scaffolding.v8i1.8520
Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-Efficacy, Reflective Thinking, and Critical Thinking: A Structural Equation Modeling Study Among Adolescents. *Islamic Guidance and Counseling Journal*, *8*(2). https://doi.org/10.25217/0020258684000
Pajares, F., & Miller, M. D. (1995). Mathematics Self-Efficacy and Mathematics Performances: The Need for Specificity of Assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022-0167.42.2.190
Paudel, K. C., & Ghimire, S. P. (2024). Mathematics Self-efficacy among Secondary Level Students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130.
Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievementA multilevel analysis of the Programme for International Student Assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014
Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' Mathematical Creative Thinking and Learning Obstacles in Solving Ill-Structured Exponential Problems. *Jurnal Didaktik Matematika*, *12*(1),

Commented [39]: Please reformat these authors according to the journal's reference style, using surnames and initials consistently. The article title should also use sentence case rather than all capital letters, unless the journal requires otherwise.

Commented [40]: A colon or full stop appears to be missing between "achievement" and "A multilevel analysis." Please correct the title after checking the original publication.

53–74. https://doi.org/10.24815/jdm.v12i1.43834
Schunk, D. H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist*, *19*(1), 48–58.
Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033
Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of mathematics self-efficacy and motivation in mathematics performance across ethnicity. *The Journal of Educational Research*, *97*(4), 208–222.
Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? *Psychology, Evaluation, and Technology in Educational Research*, *7*(2), 292–302. https://doi.org/10.33292/petier.v7i2.304
Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How Students' Self-Efficacy Can Affect Their Mathematical Critical Thinking Ability? *(Jiml) Journal of Innovative Mathematics Learning*, *8*(3), 381–387. https://doi.org/10.22460/jiml.v8i3.26650
Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11*. https://doi.org/10.3389/feduc.2026.1696182
Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 1–29. https://doi.org/10.1186/s40536-024-00204-z
Yousuf, M. I., & Rajeswari, G. (2024). Relationship between Mathematics Self Efficacy and Mathematics Achievement. *International Journal of Emerging Knowledge Studies*, *03*(10), 797–802. https://doi.org/10.70333/ijeks-03-10-011
Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987
Yulianto, D., Umami, M. R., & Mony, R. S. (2024a). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900
Yulianto, D., Umami, M. R., & Mony, R. S. (2024b). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900
Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012023
Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.986622
Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

Commented [41]: Please carefully distinguish "Yulianto" from "Yuliyanto" throughout the in-text citations. These are different author names, and the current manuscript could easily create citation mismatches.

Commented [42]: This reference is duplicated as both 2024a and 2024b with the same title, journal, pages, and DOI. Please retain only one entry and revise all corresponding in-text citations.

3. Hasil Revisi (judul berubah karena mengakomodir hasil revisi reviewer)

Journal of Advanced Sciences and Mathematics Education
Volume X, Issue X, xx -xx.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index

Comparing the Roles of Mathematical Self-Efficacy and Learning Motivation in Students' Critical Thinking Skills

Article Info

Article history:

Received: Month XX, 20XX
Revised: Month XX, 20XX
Accepted: Month XX, 20XX
(Cambria 9)

Keywords:

Critical Thinking Skills
Motivation to Learn
Maths Self-Efficacy

Abstract

ABSTRACT
Background of study: Critical thinking is an essential competency that enables students to analyse information, justify strategies, draw logical conclusions, and reflect on solutions when solving mathematical problems. Its development is influenced not only by cognitive mastery but also by affective factors, particularly learning motivation and mathematical self-efficacy. Although both constructs are frequently associated with mathematical performance, their relative contributions to students' critical thinking remain insufficiently explained.
Aims and scope of paper: This study aims to examine the structural relationships between learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving mathematical problems related to the Pythagorean theorem. It also compares the relative effects of learning motivation and mathematical self-efficacy on critical thinking.
Methods: A quantitative cross-sectional correlational design was employed. The population comprised 76 eighth-grade students at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Indonesia. A total of 34 students, consisting of 17 males and 17 females, were selected through simple random sampling. Data were collected using a learning motivation questionnaire based on the ARCS model, a mathematical self-efficacy questionnaire covering level, strength, and generality, and a critical thinking test based on Ennis' indicators. The data were analysed using Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) with LISREL 8.80. Considering the relatively small sample size, the SEM findings should be interpreted as preliminary and exploratory rather than definitive, providing initial evidence of the proposed relationships among learning motivation, mathematical self-efficacy, and critical thinking skills.
Result: The KMO value of 0.892 and a significant Bartlett's Test confirmed the suitability of the data for factor analysis. All indicators had factor loadings of 0.50 or higher and significantly represented their respective constructs. Following model reanalysis, the structural model achieved acceptable fit, with NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, and RMSEA = 0.093. Mathematical self-efficacy had a positive and significant effect on critical thinking (t = 4.40), whereas learning motivation showed a significant negative relationship (t = −2.26).
Conclusion: Mathematical self-efficacy plays a more proximal and was more strongly associated with critical thinking within the estimated model students' critical thinking than learning motivation. Students' confidence and persistence in performing mathematical tasks appear to be more directly connected to critical reasoning than their general willingness to learn.

To cite this article: Author. (20XX). Title. *Journal of Advanced Sciences and Mathematics Education, X*(X), XX-XX

Commented [1]: One reported loading is exactly 0.50 rather than above 0.50. Please revise this to "factor loadings of 0.50 or higher." This small adjustment will make the abstract consistent with Table 2.

Commented [2]: The terms "dominant" and "supporting" may be stronger than the cross-sectional evidence permits, particularly because the standardised coefficient exceeds 1.00. Please consider "was more strongly associated with critical thinking within the estimated model."

INTRODUCTION

Critical thinking has become an essential competence in mathematics education because students are expected not only to obtain correct answers but also to examine information, justify strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Aulia et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). In such situations, students must understand the problem, identify relevant information, connect mathematical concepts, compare alternative strategies, and reflect on the reasonableness of their solutions. Nevertheless, many students still experience difficulties in analysing mathematical problems, explaining the basis of their answers, and selecting appropriate problem-solving strategies. These conditions indicate that the development of critical thinking remains an important challenge in secondary mathematics education.

Students' critical thinking performance is influenced not only by cognitive knowledge but also by affective factors that shape how they approach challenging tasks. Two factors frequently associated with mathematical learning are learning motivation and mathematical self-efficacy. Learning motivation encourages students to participate, persist, and direct their efforts towards learning goals. Motivated students are generally expected to show greater attention, perseverance, and willingness to solve difficult problems. However, empirical evidence concerning the relationship between motivation and mathematical thinking has not always been consistent. Alotaibi, for example, found that academic self-motivation showed limited or no dependence on the mathematical thinking of secondary school students (Alotaibi, 2020). This finding suggests that students' willingness to learn may not automatically translate into the ability to analyse, evaluate, and solve mathematical problems critically.

Mathematical self-efficacy refers to students' beliefs about their capacity to perform mathematical tasks successfully (Chan et al., 2022; Farah Deeba, Sana Hafeez, Shazia Noureen, 2021; Pajares & Miller, 1995; et al., 2024; Yuliyanto et al., 2021; Zakariya, 2022). Unlike general interest or willingness to learn, self-efficacy is closely related to students' judgments about whether they can organise and carry out the actions required to solve a particular problem. Students with strong self-efficacy are more likely to attempt challenging questions, maintain effort after experiencing difficulty, test alternative strategies, and interpret mistakes as part of the learning process. Conversely, students who doubt their mathematical capabilities may avoid complex tasks, rely excessively on procedural routines, or abandon problem-solving efforts prematurely. Recent research shows that mathematics self-efficacy among secondary students varies across groups and educational levels, emphasising the need for systematic support to strengthen students' confidence in learning mathematics (Paudel & Ghimire, 2024).

Previous studies have provided evidence of a positive relationship between self-efficacy and mathematical critical thinking. Yulianto et al. reported that self-efficacy contributed significantly to students' critical mathematical thinking and interacted with the instructional approach used in mathematics classrooms (Yulianto et al., 2024a). Similarly, Marlena and Nugraheni found a strong positive correlation between self-efficacy and critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). These findings indicate that students' confidence in their mathematical capabilities may serve as an important affective foundation for engaging in complex reasoning. However, much of the existing research has examined self-efficacy in relation to critical thinking as a single association, compared critical thinking across self-efficacy levels, or investigated self-efficacy within particular instructional interventions.

Several important research gaps remain. First, previous studies have frequently examined learning motivation and mathematical self-efficacy as separate predictors of mathematical thinking. Alotaibi, for example, investigated the relationship between academic self-motivation and mathematical thinking among secondary school students but did not include mathematical self-efficacy as a competing predictor [1]. Conversely, contribution of self-efficacy to students' mathematical critical thinking across different instructional approaches without simultaneously estimating the unique effect of learning motivation [2]. Mathematical self-efficacy and critical thinking in Pythagorean theorem tasks, rather than comparing self-efficacy with learning motivation within a common structural model [3]. These studies provide evidence that each affective construct may be associated with mathematical thinking, but they do not establish whether either construct retains a meaningful unique contribution when their shared variance is statistically controlled. Second, studies that have considered motivation and self-efficacy together have often focused on their simultaneous development through instructional interventions rather than on their relative effects on critical thinking. For instance, In'am and Sutrisno reported that cooperative learning strengthened both students' motivation and self-efficacy, but their study did not compare the independent predictive contribution of each construct to mathematical critical thinking [4]. More recent integrated models have positioned motivation as an upstream factor and self-efficacy as a more proximal mechanism of mathematical problem solving; however, these models have focused on general problem-solving performance rather than specifically on critical thinking in Pythagorean tasks [5]. Third, the existing literature generally assumes that stronger motivation supports engagement and higher-order thinking, while paying less attention to the possibility that the direction or magnitude of its partial effect may change after mathematical self-efficacy is included in the same model. Finally, research

focusing specifically on students' critical thinking when solving Pythagorean problems remains limited, even though such tasks require students to interpret information, identify relevant mathematical relationships, select and justify strategies, and draw logically defensible conclusions. The present study therefore addresses these gaps by simultaneously estimating and comparing the unique structural contributions of learning motivation and mathematical self-efficacy to students' critical thinking skills.

Accordingly, the novelty of this study lies in examining learning motivation and mathematical self-efficacy simultaneously and comparing their relative roles as predictors of students' critical thinking skills. Rather than merely determining whether both affective variables correlate with critical thinking, this study investigates which construct provides the stronger direct contribution when the variables are analysed within the same structural model. This comparative perspective is important because students may possess a strong desire to learn but still hesitate when they do not believe that they can complete a mathematical task successfully. Thus, the study distinguishes between students' willingness to engage in learning and their confidence in performing the cognitive actions required for critical problem solving.

This study therefore aims to predictive contributions of learning motivation and mathematical self-efficacy on students' critical thinking skills in solving mathematics problems. Accordingly, this study addresses the following research questions:

RQ.1 Does learning motivation significantly predict students' critical thinking skills in solving Pythagorean theorem problems?

RQ.2 Does mathematical self-efficacy significantly predict students' critical thinking skills in solving Pythagorean theorem problems?

RQ.3 What are the relative contributions of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills when both variables are simultaneously estimated using Structural Equation Modeling (SEM)?.

By clarifying their relative contributions, the findings are expected to provide a more precise basis for designing mathematics instruction that not only stimulates students' interest and persistence but also strengthens their confidence in analysing, reasoning, and solving challenging mathematical problems.

Commented [3]: Because this is a cross-sectional correlational study, "effects" may imply causality. Please use "associations," "relationships," or "predictive contributions" consistently throughout the manuscript.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participants

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected using a simple random sampling technique. Each student in the population was assigned an identification number, and the participants were selected using a computer-generated random-number procedure, ensuring that every student had an equal probability of being included in the study. All selected students agreed to participate, completed the research procedures, and provided complete datasets; therefore, no participants were excluded from the final analysis.

Prior to data collection, permission to conduct the study was obtained from the school administration. Written informed consent was obtained from the students' parents or legal

guardians, and assent was obtained from all participating students. The participants were informed about the objectives of the study, and participation was entirely voluntary. According to the institutional policy, formal ethics committee approval was not required for this educational research involving minimal risk. All collected data were treated confidentially and used solely for research purposes.

Instruments

Three research instruments were employed.

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, comprising four dimensions: Attention, Relevance, Confidence, and Satisfaction. The instrument consisted of [insert number] items, each rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of learning motivation. Representative items included "I pay close attention during mathematics lessons" (Attention), "The mathematics lessons are relevant to my daily life" (Relevance), "I am confident that I can successfully complete mathematics tasks" (Confidence), and "I feel satisfied after successfully solving mathematics problems" (Satisfaction). Negatively worded items, if any, were reverse-coded prior to data analysis so that higher scores consistently reflected higher learning motivation. The instrument was adapted from Keller's ARCS motivational framework and demonstrated good internal consistency, with a Cronbach's alpha/Construct Reliability (CR) of [insert value] in the present study. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework (Bandura, 2006). The instrument measured three dimensions of mathematical self-efficacy: Level, Strength, and Generality, reflecting students' confidence in performing mathematical tasks with varying levels of complexity, persistence in overcoming mathematical difficulties, and the transferability of their confidence across different mathematical situations. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of mathematical self-efficacy. The instrument was translated and adapted to the Indonesian junior high school context and was reviewed by mathematics education experts to ensure linguistic clarity, cultural appropriateness, and content validity prior to administration.The instrument measured three dimensions:

a. Level
b. Strength
c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks specifically related to the Pythagorean Theorem with varying levels of complexity. The items were designed to assess students' beliefs in their capability to understand Pythagorean concepts, select appropriate solution strategies, solve contextual Pythagorean problems, and justify their mathematical reasoning. This domain-specific approach is consistent with Bandura's recommendation that self-efficacy should be measured as closely as possible to the target performance domain in order to enhance its predictive validity.

Critical Thinking Test

Students' critical thinking skills were assessed using an essay-based mathematics test developed within the context of the Pythagorean Theorem. The instrument was constructed based on Ennis' critical thinking framework and measured five dimensions: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The test consisted of essay problems requiring students to analyse contextual mathematical situations, identify relevant information, justify their solution strategies, perform mathematical reasoning, and explain the validity of their conclusions. Students completed the test during the allocated instructional period under teacher supervision. Responses were evaluated using an analytic scoring rubric aligned with

the five critical thinking dimensions proposed by Ennis, with higher scores indicating higher levels of critical thinking performance. To ensure scoring consistency, all responses were assessed independently by two mathematics education lecturers using the same scoring rubric. Any discrepancies in scoring were resolved through discussion until consensus was reached. Prior to implementation, both the instrument and the scoring rubric were reviewed by mathematics education experts to establish content validity.The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:

a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

Prior to implementation, all research instruments were subjected to expert judgment to establish content validity. The validation process involved three experts in mathematics education, each holding a doctoral degree and having extensive experience in mathematics teaching, educational assessment, and instrument development. The experts evaluated the instruments in terms of content relevance, construct representation, language clarity, readability, and suitability for junior high school students. The degree of agreement among the experts was quantified using Aiken's V, and all items achieved values above the recommended threshold for acceptable content validity. Based on the experts' recommendations, several items were revised to improve wording, clarity, and alignment with the intended constructs before the instruments were administered in the main study.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Data Analysis

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, the underlying statistical assumptions were evaluated. The assessment indicated that the data satisfied the assumptions required for Structural Equation Modeling. Multivariate normality was examined using LISREL, and the results indicated that the data did not exhibit substantial departures from multivariate normality. Multicollinearity was assessed by examining the correlations among the latent constructs as well as the tolerance and Variance Inflation Factor (VIF) values. The results showed no evidence of problematic multicollinearity, with all tolerance values exceeding 0.10 and all VIF values remaining below the recommended threshold of 10. In addition, tests of linearity and homogeneity confirmed that the data met the assumptions necessary for SEM analysis. These findings indicate that the estimated structural relationships were not adversely affected by violations of the underlying statistical assumptions and that the proposed model was appropriate for subsequent hypothesis testing.

The measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50.

The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual

Commented [4]: CR and AVE should normally be calculated and reported separately for learning motivation, mathematical self-efficacy, and critical thinking. The manuscript currently appears to provide one overall CR and AVE across all 12 indicators. Please clarify and preferably report construct-specific values.

Commented [5]: Please identify the estimation method used, such as maximum likelihood, robust maximum likelihood, or another estimator. Also explain how ordinal Likert responses, missing values, and potential non-normality were handled.

(SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values.

Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 (α = 0.05). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

Commented [6]: The manuscript states that R^2 was used, but the value does not appear in the Results section. Please report R^2 for critical thinking and ensure that it is discussed in relation to the third research question.

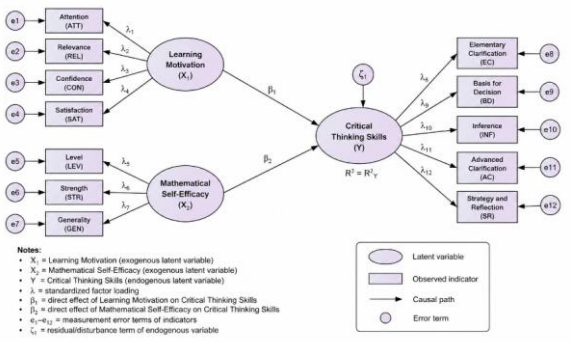


Figure 1. Proposed structural equation model of the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills.

RESULTS AND DISCUSSION

RESULTS

Preliminary Analysis

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis.

The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test	Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared

substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result (χ^2 = 1307.307, df = 66, p < 0.001), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis.

Overall, the KMO measure and Bartlett's Test indicate that the data were suitable for factor analysis and provided an appropriate basis for conducting Confirmatory Factor Analysis (CFA). However, the adequacy of the measurement model was primarily established through the CFA results, including standardized factor loadings, construct reliability, and convergent validity, which collectively demonstrated that the proposed measurement model was acceptable for subsequent structural model analysis. Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL.

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model.

Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

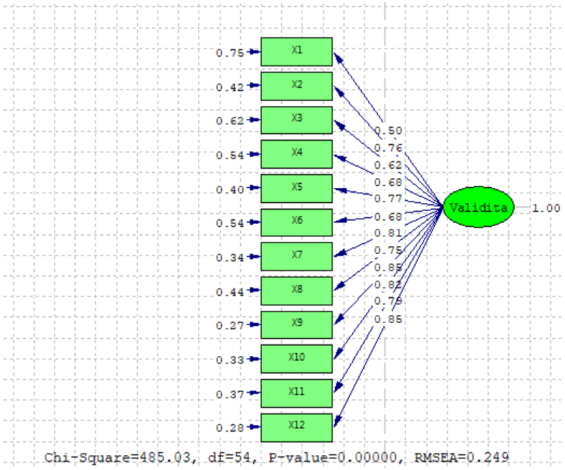


Figure 2. CFA Test

Commented [7]: Please clarify what model Figure 2 represents. The figure appears to combine all indicators into one general factor labelled "Validitas," whereas the proposed study contains three distinct constructs. The figure also displays poor initial fit, including RMSEA = 0.249, which needs to be explained rather than followed immediately by a claim of satisfactory validity.

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Commented [8]: Please map X1–X12 to their respective constructs and named dimensions. Readers should not have to infer which indicators measure motivation, self-efficacy, or critical thinking. Please also use English throughout the caption and column headings.

Construct Reliability (CR)

$$CR = \frac{(\sum\lambda)^2}{(\sum\lambda)^2 + \sum\varepsilon}$$

Calculation results:

$$\sum\lambda = 8{,}58$$
$$(\sum\lambda)^2 = 73{,}62$$
$$\sum\varepsilon = 5{,}30$$

so that

$$CR = \frac{73{,}62}{73{,}62 + 5{,}30} = 0{,}933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.

Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum\lambda^2}{n}$$

Sum of squared loadings

$$\sum\lambda^2 = 6{,}70$$

with

$$n = 12$$

so

$$AVE = \frac{6{,}70}{12} = 0{,}558$$

AVE = 0,558
The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity.

In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). Construct validity was evaluated using standardized factor loadings for each latent construct, whereas construct reliability was assessed separately for Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking Skills using Composite Reliability (CR) and Average Variance Extracted (AVE). The results demonstrated satisfactory internal consistency and convergent validity for all three constructs, with CR values exceeding the recommended threshold of 0.70 and AVE values exceeding 0.50, indicating that each construct exhibited adequate reliability and explained more than half of the variance of its respective indicators. The construct-specific CR and AVE values are presented in Table 3.

Tabel 3. Construct Reliability and Convergent Validity of Each Latent Construct

Construct	Number of Indicators	Composite Reliability (CR)	Average Variance Extracted (AVE)	Interpretation
Learning Motivation	4	**0.738**	**0.418**	Reliable; convergent validity below the recommended threshold
Mathematical Self-Efficacy	3	**0.800**	**0.572**	Reliable and convergently valid
Critical Thinking Skills	5	**0.907**	**0.662**	Highly reliable and convergently valid

Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Structural Model Evaluation

After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data.

The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI = 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, the measurement model was re-specified based on the Modification Indices (MI) generated by LISREL. Model refinement was limited to correlating measurement error terms between indicators belonging to the same latent construct when supported by both the Modification Indices and theoretical considerations. Specifically, residual correlations were added between eX2–eX3 (Learning Motivation), eY1–eY2 (Mathematical Self-Efficacy), and eZ2–eZ3 (Critical Thinking), as these indicator pairs measured closely related

aspects of the same construct and shared similar wording and conceptual content. The corresponding Modification Indices exceeded the recommended threshold (MI > 3.84), indicating that correlating these residuals would substantially improve model fit. No cross-construct residual correlations or additional structural paths were introduced, thereby preserving the theoretical structure of the proposed model. Following these theoretically justified modifications, the goodness-of-fit indices improved substantially (NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, RMSEA = 0.093), indicating that the revised model provided a better representation of the observed data. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. Most goodness-of-fit indices satisfied the recommended criteria, indicating that the revised model achieved an acceptable overall fit. The incremental fit indices demonstrated good model fit (NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94), whereas the RMSEA value (0.093) indicated a marginal but still acceptable level of approximation. Collectively, these results suggest that the revised structural model provides an adequate representation of the observed data and is appropriate for subsequent hypothesis testing, with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement.

The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

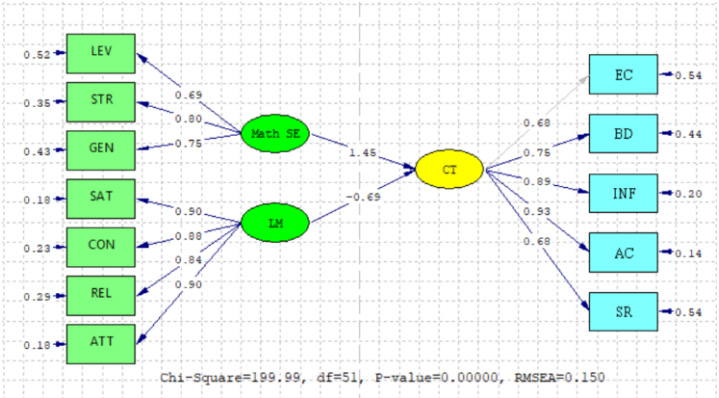


Figure 3. Model SEM

Tabel 4. Goodness-of-Fit model

No	Goodness of Fit	Analysis Results		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,88	Not Good
2	GFI	≥ 90	0.88	Not Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good

Commented [9]: Table 3 classifies RMSEA = 0.150 as "Good," whereas the surrounding narrative correctly describes it as high and indicative of poor fit. Please correct this decision and complete the currently empty "Cut of Value" column.

5	RMSEA	≥ 0.08	0,150	Not Good

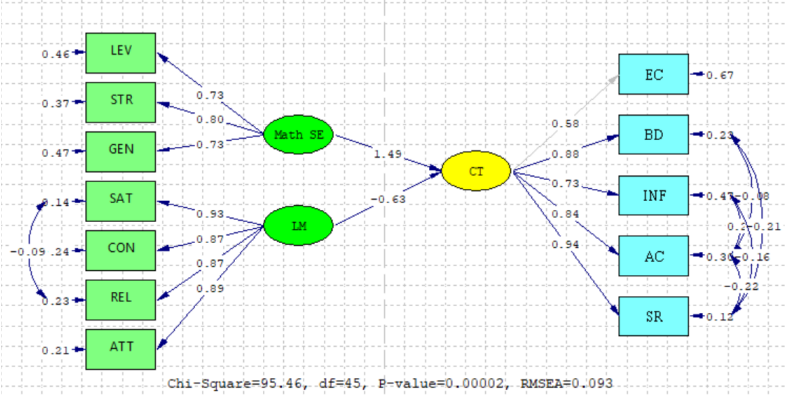


Figure 4. Re-analysis of the SEM Model

Tabel 5. Reanalisis Goodness-of-Fit model

No	Goodness of Fit	Analysis Results		
		Cut of Value	Value	Decision
1	NNFI	≥ 90	0,97	Good
2	CFI	≥ 90	0.98	Good
3	NFI	≥ 90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≥ 0.08	0,093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero.

As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value (|−2.26| = 2.26) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction.

These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the structural relationships were interpreted based on both the statistical significance and the direction of the estimated path coefficients. The results indicated that the effect of Mathematical Self-Efficacy on Critical Thinking Skills was statistically significant and consistent with the hypothesised positive direction, thereby supporting the proposed hypothesis. In contrast, although the effect of Learning Motivation on Critical Thinking Skills was statistically significant, the estimated coefficient was negative rather than positive. Consequently, this relationship cannot be considered supportive

of the original directional hypothesis and should instead be interpreted as evidence of a statistically significant inverse association within the present sample.

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level.

As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Table X presents the structural parameter estimates obtained using the Maximum Likelihood estimation procedure in LISREL 8.80. Mathematical Self-Efficacy had a positive and statistically significant effect on Critical Thinking Skills (B = 1.25, SE = 0.29, t = 4.40, p < 0.001), indicating that higher levels of mathematical self-efficacy were associated with higher levels of critical thinking. In contrast, Learning Motivation showed a statistically significant negative effect on Critical Thinking Skills (B = −0.53, SE = 0.23, t = −2.26, p = 0.024). Although statistically significant, the direction of the coefficient was opposite to the hypothesised positive relationship; therefore, the hypothesis regarding the positive effect of Learning Motivation was not supported. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

Table 6. Structural Path Estimates

Structural Path	Unstandardized Coefficient (B)	Standard Error (SE)	*t*-value	*p*-value	Decision
Learning Motivation → Critical Thinking	**−0.53**	**0.23**	**−2.26**	**0.024**	Significant, but hypothesis **not supported**
Mathematical Self-Efficacy → Critical Thinking	**1.25**	**0.29**	**4.40**	**< 0.001**	**Supported**

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold (|−2.26| > 1.96), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy.

Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

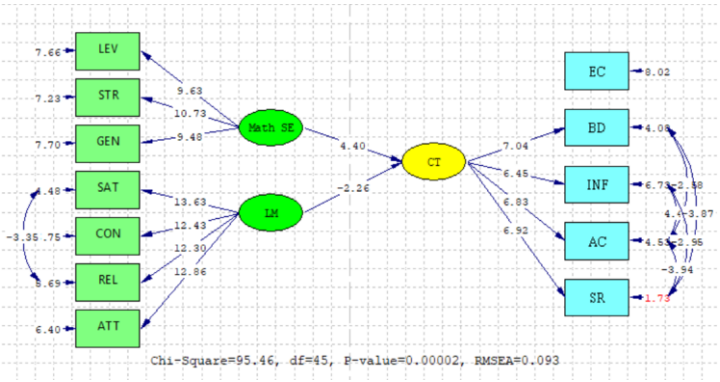


Figure 5. t-value Model SEM

DISCUSSION

The findings of this study indicate that students' critical thinking skills are determined not only by their mastery of mathematical concepts but also by their beliefs and internal drives when confronting mathematical problems. The proposed structural model identifies learning motivation and mathematical self-efficacy as two affective factors that explain students' ability to clarify problems, use evidence as a basis for judgment, draw inferences, provide further explanations, and determine appropriate problem-solving strategies. Following model refinement, the structural model demonstrated a substantially improved fit to the empirical data, as reflected by NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94. In addition, the reduction in RMSEA from 0.150 to 0.093 indicates that the discrepancy between the theoretical model and the observed data was considerably reduced. Although the RMSEA value remains above the threshold for a close fit, it falls within the range generally considered to represent an acceptable or marginal model fit, thereby supporting the use of the revised model for hypothesis testing.

Structure of the Learning Motivation Construct

The construct of learning motivation was represented by four indicators: attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. These values indicate that all four indicators provide strong representations of students' learning motivation. Among them, attention and satisfaction exhibited the highest factor loadings (0.90), suggesting that students' motivation is primarily reflected in their ability to maintain attention during learning activities and in the satisfaction they experience after completing mathematical tasks or participating in classroom learning.

The prominence of the attention indicator suggests that students' initial engagement plays a fundamental role in sustaining learning motivation. Students who are able to focus their attention tend to be more receptive to new information, actively participate in problem-solving processes, and remain engaged throughout learning activities. Likewise, the strong contribution of satisfaction indicates that experiences of success, recognition, and perceived learning benefits reinforce students' motivation. These findings imply that learning motivation is not merely an antecedent of learning but is continuously strengthened through positive learning experiences and successful task completion.

The confidence indicator produced a standardized loading factor of 0.88. Although confidence is conceptualized as one of the four dimensions of the ARCS motivational model, it differs conceptually from mathematical self-efficacy, which constitutes a separate latent construct in this study. Within the ARCS framework, confidence reflects students' general expectations of success during the learning process, whereas mathematical self-efficacy refers to students' beliefs about their capability to perform specific mathematical tasks successfully. This conceptual proximity should be carefully considered because it may generate empirical overlap between learning motivation and mathematical self-efficacy. Such overlap provides a plausible explanation for why the structural path

from learning motivation to critical thinking became negative when both constructs were estimated simultaneously within the same structural model.

The present findings are consistent with the study conducted by In'am and Sutrisno, who reported that the Teams Games Tournament (TGT) cooperative learning model enhanced both students' learning motivation and mathematical self-efficacy through intensive peer interaction and shared experiences of success (In'am & Sutrisno, 2021). Their findings also suggest that learning motivation and self-efficacy tend to develop simultaneously during instructional activities, making the two constructs difficult to distinguish empirically. Consequently, when both variables are incorporated into a single structural equation model, a degree of conceptual and statistical overlap may occur, potentially influencing the direction and magnitude of the estimated structural coefficients.

Struktur konstruk self-efficacy matematis

Mathematical self-efficacy was measured using three indicators: level, strength, and generality, with standardized factor loadings of 0.69, 0.80, and 0.75, respectively. Among these dimensions, strength emerged as the strongest indicator of mathematical self-efficacy. This finding suggests that students' self-efficacy is primarily reflected in the strength of their belief that they can persist when confronted with mathematical challenges, rather than merely in their willingness to undertake tasks of varying levels of difficulty.

The dominance of the strength dimension has important implications for the development of critical thinking skills. Solving mathematical problems that require critical thinking rarely leads to immediate solutions. Instead, students are often required to test alternative strategies, identify and correct errors, revise their approaches, and continuously evaluate the appropriateness of their solutions. Under such circumstances, the strength of students' self-beliefs determines whether they remain engaged in the problem-solving process or abandon their efforts after encountering initial failure. Therefore, mathematical self-efficacy should be viewed not simply as a positive perception of one's own abilities, but as a psychological resource that sustains persistence and supports higher-order cognitive processes during complex mathematical reasoning.

The generality dimension, with a standardized loading of 0.75, indicates that students with higher mathematical self-efficacy tend to transfer their confidence across different mathematical contexts. In contrast, the level dimension exhibited the lowest loading (0.69), suggesting that students' confidence in dealing with progressively more difficult mathematical tasks is relatively weaker than their determination to persist. In other words, students may remain motivated to continue working on mathematical problems, yet their confidence may decline as the complexity of the tasks increases substantially.

These findings are consistent with the study by Yulianto, Umami, and Mony, who reported that mathematical self-efficacy makes a significant contribution to students' critical thinking skills. Their study further demonstrated that the influence of self-efficacy is moderated by the instructional approach adopted in the classroom, highlighting the interaction between affective and pedagogical factors in promoting higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Mawaddah et al., 2026; Sudiartini et al., 2025). Similarly, Yang, Maeda, and Gentry, using data from the National Assessment of Educational Progress (NAEP), identified mathematical self-efficacy as a robust predictor of mathematics achievement across different grade levels, even after controlling for student- and school-level characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these studies support the view that mathematical self-efficacy represents a proximal psychological factor that directly influences students' cognitive engagement and their capacity to think critically when solving mathematical problems.

Structure of the Critical Thinking Construct

The construct of critical thinking was represented by five indicators: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The standardized factor loadings ranged from 0.68 to 0.93, indicating that all indicators made meaningful contributions to the latent construct. Among these dimensions, advanced clarification exhibited the highest loading (0.93), followed by inference (0.89). These findings suggest that students' critical thinking skills are most strongly reflected in their ability to provide well-reasoned explanations and to draw logical conclusions based on the information available and the problem-solving processes they employ.

The prominence of advanced clarification indicates that critical thinking extends beyond simply obtaining correct answers. Rather, it is demonstrated through students' ability to justify the strategies they select, establish logical connections among relevant information, identify underlying assumptions, and clarify the reasoning that supports their conclusions. In mathematics education, this dimension is particularly important because a correct numerical answer does not necessarily reflect a deep conceptual understanding. Students may arrive at the correct solution by applying memorized procedures, yet still be unable to explain why those procedures are appropriate or mathematically justified. Therefore, encouraging students to articulate their reasoning is an essential component of fostering higher-order thinking.

The strong loading of the inference dimension further highlights that drawing logical conclusions constitutes a central component of critical thinking within the proposed model. Students are expected not only to perform mathematical calculations but also to interpret the results, evaluate the available evidence, and formulate conclusions that are logically coherent and mathematically defensible. This finding suggests that critical thinking progresses from understanding and processing information toward constructing reasoned judgments supported by evidence.

In contrast, elementary clarification and strategy and reflection exhibited the lowest standardized loadings (0.68 each). Although both indicators remained statistically significant and met the acceptable validity criteria, their relatively lower contributions suggest that students are less proficient in identifying the core elements of a problem and critically evaluating their own solution strategies than they are in explaining reasoning and drawing inferences. The comparatively weaker contribution of strategy and reflection may indicate that many students tend to stop once they obtain an answer, without verifying the accuracy of their reasoning, considering alternative solution strategies, or reflecting on the efficiency and appropriateness of their problem-solving process. Such tendencies may limit the development of deeper metacognitive skills that are fundamental to effective mathematical reasoning.

These findings have important implications for mathematics instruction. Developing students' critical thinking skills requires more than presenting increasingly difficult mathematical problems. Teachers should create learning environments that encourage students to identify relevant information, clarify problem requirements, compare alternative solution strategies, justify their reasoning, and critically evaluate the validity and efficiency of their solutions. Contextual and problem-based learning effectively promotes critical thinking by providing students with meaningful opportunities to analyze real-world situations, select appropriate strategies, justify their reasoning, and reflect on the quality of their solutions (Anggraeni et al., 2023; Yu & Zin, 2023). Such instructional approaches not only improve mathematical performance but also cultivate the reflective and analytical thinking processes that characterize effective critical thinkers.

The Effect of Mathematical Self-Efficacy on Critical Thinking Skills

The structural analysis indicates that mathematical self-efficacy has a positive and significant effect on critical thinking skills, with a T-value of 4.40. These findings confirm that students' belief in their ability to solve math problems plays a significant role in supporting higher-order thinking activities. Students with strong self-efficacy tend to be better prepared to tackle non-routine problems, persevere when encountering obstacles, and use mistakes as a basis for refining their strategies.

This influence can be explained by the close relationship between self-efficacy and the task-solving process. Critical thinking requires sustained cognitive engagement, while self-efficacy determines the extent to which students are willing to activate and maintain that engagement. When students are confident in their ability to solve problems, their cognitive resources are more likely to be directed toward problem analysis rather than toward anxiety, doubt, or the desire to avoid the task. Self-efficacy makes a significant contribution to mathematical critical thinking ability (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). These findings are also consistent with research showing that self-efficacy is a strong predictor of mathematics achievement from elementary through high school. Although mathematical achievement differs from critical thinking, both findings point to a similar mechanism: belief in one's own abilities supports the courage to make decisions, sustain effort, and manage difficulties in mathematical tasks.

Mathematical self-efficacy and mathematical thinking are the closest direct predictors of problem-solving ability. In their model, motivation functions as an upstream factor, while its influence on

problem-solving is mediated through more proximal processes, particularly self-efficacy and mathematical thinking. These findings help explain the results of this study, which show that self-efficacy has a stronger direct influence on critical thinking than learning motivation.

Relationship Between Learning Motivation and Critical Thinking Skills

The structural path from Learning Motivation to Critical Thinking yielded a t-value of −2.26. Because the absolute value exceeds the critical threshold of 1.96, the relationship is statistically significant; however, the estimated effect is negative. This finding should not be interpreted as evidence that learning motivation inherently diminishes students' critical thinking skills. Rather, the negative coefficient should be understood within the context of the structural model, in which mathematical self-efficacy was simultaneously included as a predictor.

When examined independently, learning motivation is generally expected to be positively associated with students' engagement in learning activities. However, after controlling for the variance shared with mathematical self-efficacy, the unique contribution of learning motivation may exhibit a different relationship with critical thinking. This pattern may reflect a suppression effect or substantial conceptual overlap between the two constructs, particularly because the confidence dimension of the ARCS motivational model is conceptually related to mathematical self-efficacy. Consequently, the negative coefficient should not be interpreted as suggesting that attention, relevance, satisfaction, or the desire to learn are detrimental to critical thinking. Instead, it indicates that learning motivation, in the absence of strong beliefs about one's mathematical competence, may not necessarily translate into effective critical thinking performance.

Students may demonstrate high levels of attention, perceive mathematics as relevant, and possess a strong desire to achieve positive learning outcomes, yet still struggle when required to select appropriate problem-solving strategies, tolerate uncertainty, or justify mathematical reasoning. Under these circumstances, learning motivation provides the impetus to engage in learning, whereas mathematical self-efficacy determines whether this motivation can be transformed into effective cognitive action. Therefore, learning motivation can be viewed as the factor that initiates students' engagement, while mathematical self-efficacy functions as the proximal operational belief that enables students to persist, regulate their efforts, and successfully perform complex mathematical tasks.

This interpretation is consistent with previous research suggesting that learning motivation functions as an upstream motivational predictor, whereas self-efficacy serves as a more proximal psychological mechanism underlying successful problem solving (Bandura, 1982, 2014; Schunk, 1984). Likewise, In'am and Sutrisno reported that cooperative learning experiences simultaneously enhance students' learning motivation and mathematical self-efficacy, indicating that the two constructs tend to develop together rather than independently (Holenstein et al., 2022; Stevens et al., 2004; Zimmerman, 2000). These findings imply that instructional interventions should extend beyond increasing students' interest in learning by providing authentic mastery experiences that transform motivation into confidence in mathematical competence.

Nevertheless, the negative structural coefficient should be interpreted with caution. The standardized structural model yielded a coefficient of 1.48 for the path from Mathematical Self-Efficacy to Critical Thinking Skills and −0.63 for the path from Learning Motivation to Critical Thinking Skills. These values were verified against the LISREL estimates and are reported consistently in Figure 4, Table X, and the narrative presentation of the results. A standardized coefficient exceeding 1.00 may indicate statistical issues such as multicollinearity, a suppression effect, excessively high correlations among predictors, or an improper estimation solution, including the possibility of a Heywood case. Therefore, before drawing substantive conclusions, it is important to examine the correlation between learning motivation and mathematical self-efficacy, the associated standard errors, the covariance matrix, and other diagnostic information provided by LISREL. Without these additional evaluations, the magnitude of the positive effect of self-efficacy and the negative effect of learning motivation may be overinterpreted.

The refinement of the structural model improved its overall fit by allowing correlations among several measurement errors based on the diagnostic information generated by LISREL. Statistically, this procedure substantially improved the model's goodness-of-fit indices. However, correlated error terms should be introduced only when supported by substantive theoretical justification rather than

solely to improve model fit. Within the learning motivation construct, correlated errors may arise because certain questionnaire items share similar wording, contexts, or response patterns. Likewise, correlated errors among the critical thinking indicators may occur because several dimensions were assessed using related mathematical tasks or common problem-solving processes, resulting in shared variance that is not fully explained by the general latent construct.

Overall, the model refinement did not alter the underlying theoretical assumption that both learning motivation and mathematical self-efficacy are associated with students' critical thinking skills. Instead, it suggests that the relationships among the observed indicators are more complex than initially assumed, particularly when the independence of measurement errors is relaxed. Although the refined model demonstrates a substantially better fit to the empirical data, the RMSEA value of 0.093 indicates that some degree of model misfit remains. Accordingly, the final model is more appropriately described as exhibiting an acceptable (or marginal) fit rather than an excellent or close fit.

Theoretical and Educational Implications

The primary theoretical contribution of this study lies in distinguishing the roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills. Although both constructs represent important affective dimensions of learning, they operate through different psychological mechanisms. Learning motivation explains why students are willing to participate in learning activities, whereas mathematical self-efficacy explains whether students believe they possess the capability to perform the cognitive tasks required. In the context of mathematical critical thinking, this operational belief appears to be more directly associated with analyzing information, selecting appropriate strategies, drawing logical conclusions, and sustaining effort throughout complex problem-solving processes. From a pedagogical perspective, these findings suggest that mathematics instruction should extend beyond making learning activities interesting or personally relevant. Teachers should intentionally foster students' mathematical self-efficacy by providing challenging yet attainable tasks, offering graduated instructional support, delivering strategy-oriented feedback, incorporating peer modeling, and creating opportunities for students to learn from and correct their mistakes. Contextual and problem-based learning approaches can effectively support these objectives, provided that the complexity of mathematical tasks is carefully calibrated to ensure that students experience genuine mastery rather than repeated failure. Previous studies have similarly shown that contextual and problem-based learning simultaneously promotes critical thinking and strengthens students' mathematical self-efficacy (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024b).

Particular attention should also be given to the relatively weaker dimensions of critical thinking identified in this study, namely elementary clarification and strategy and reflection. Teachers can strengthen these dimensions by routinely encouraging students to ask reflective questions such as: What information is provided? What is actually being asked? Why is this strategy appropriate? Are there alternative approaches? How can the correctness of the solution be verified? Such reflective practices are likely to strengthen the relationship between students' self-efficacy and the quality of their mathematical reasoning, ensuring that confidence is accompanied by genuine conceptual understanding and effective problem-solving competence.

Overall, the findings of this study indicate that mathematical self-efficacy represents the affective factor most directly associated with students' critical thinking skills. Although learning motivation remains an essential component of successful learning, its influence should be understood within a broader psychological framework in which its effects may operate through mathematical self-efficacy, self-regulated learning, persistence, and cognitive engagement during problem solving. Consequently, fostering students' critical thinking requires instructional approaches that simultaneously cultivate the desire to learn, strengthen confidence in mathematical competence, and develop habits of reflective and analytical thinking.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently.

Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self-efficacy. Teachers are encouraged to design learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the research involved a relatively small sample of 34 eighth-grade students from a single junior high school, limiting the generalizability of the findings to broader educational contexts. Second, the study focused exclusively on the Pythagorean theorem, meaning that the structural relationships identified may differ when applied to other mathematical topics with different cognitive characteristics. Third, the research adopted a cross-sectional design, which captures relationships among variables at a single point in time and therefore does not explain how learning motivation, mathematical self-efficacy, and critical thinking develop longitudinally. Finally, although the reanalyzed SEM model achieved acceptable goodness-of-fit indices, the RMSEA value (0.093) indicates that there is still room for improving the structural model by considering additional variables or alternative model specifications.

Suggestions

Future research is recommended to involve larger and more diverse samples from different schools and educational levels to improve the generalizability of the findings. Longitudinal or experimental studies are also needed to examine the causal development of critical thinking and to evaluate how instructional interventions enhance mathematical self-efficacy over time. In addition, future studies should incorporate other psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, problem-solving strategies, or classroom learning environment, to obtain a more comprehensive explanation of students' critical thinking skills.

From a practical perspective, mathematics teachers are encouraged to prioritize instructional strategies that strengthen students' mathematical self-efficacy through meaningful problem-solving experiences, guided practice, reflective discussion, and constructive feedback. Rather than merely increasing students' motivation to learn, instructional practices should cultivate confidence in applying mathematical knowledge, as this study indicates that mathematical self-efficacy is the affective factor most directly associated with students' critical thinking skills.

Conclusion

This study investigated the structural relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using Structural Equation Modeling (SEM). Overall, the measurement model demonstrated generally acceptable psychometric properties. The results indicated adequate sampling adequacy and satisfactory construct reliability across the three latent constructs. Convergent validity was fully supported for the Mathematical Self-Efficacy and Critical Thinking constructs, whereas the Learning Motivation construct exhibited acceptable reliability but a slightly lower Average Variance Extracted (AVE) than the recommended threshold. Considering the relatively small sample size and the model re-specification based on theoretically justified modification indices, these findings should be

interpreted with appropriate caution. Nevertheless, the measurement model provides sufficient empirical support for subsequent structural model analysis. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data.

The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence, analytical reasoning, and reflective thinking when confronting complex mathematical tasks.

The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

References

Agusman, Purwanto, & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the Relationship between Academic Self-motivation and the Mathematical Thinking: A Case Study of Secondary School Students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101334

Aulia, H. D., Umbara, D., Jupri, A., & Dahlan, J. A. (2025). Mathematical Critical Thinking Ability of Grade IX Students in Solving Ill-Structured Problems. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *15*(1), 185–194. https://doi.org/10.30998/formatif.v15i1.27337

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the Impact of Discovery Learning and Self-Efficacy on Students' Critical Thinking Skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4). https://doi.org/10.35445/alishlah.v17i4.7134

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122.

Bandura, A. (2014). Exercise of personal agency through the self-efficacy mechanism. In *Self-efficacy* (pp. 3–38). Taylor & Francis.

Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807

Cahyani, V. F., & Setyaningsih, R. (2024). The Implementation of Problem-Based Learning to Enhance Critical Thinking Skills in Solving Contextual Mathematics Problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29

Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement Model and Adaptation of Self-Efficacy toward Mathematics Reasoning among University Students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114

Farah Deeba, Sana Hafeez, Shazia Noureen. (2021). AN INVESTIGATION OF 10th GRADE STUDENTS' SELF-EFFICACY BELIEFS IN MATHEMATICS. *Pakistan Journal of Educational Research*, *4*(1). https://doi.org/10.52337/pjer.v4i1.145

Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007

Holenstein, M., Bruckmaier, G., & Grob, A. (2022). How do self-efficacy and self-concept impact mathematical achievement? The case of mathematical modelling. *British Journal of Educational*

Psychology, *92*(1), e12443.

In'am, A., & Sutrisno, E. S. (2021). Strengthening Students' Self-Efficacy and Motivation in Learning Mathematics through the Cooperative Learning Model. *International Journal of Instruction*, *14*(1), 395–410.

Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2394738

Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140

Marlena, L., & Nugraheni, E. A. (2026). The Correlation Between Self-Efficacy and Critical Thinking Skills of Senior High School Students on the Pythagorean Theorem Material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587

Masitoh, L. F., & Fitriyani, H. (2018). Improving students' mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30.

Mawaddah, S., Syahri, M., & Soenaryo, S. F. (2026). The Application of Guided Inquiry to Students' Critical Thinking Skills in Pancasila Education Subjects with Self-Efficacy As a Moderator Variable. *Scaffolding: Jurnal Pendidikan Islam Dan Multikulturalisme*, *8*(1), 225–244. https://doi.org/10.37680/scaffolding.v8i1.8520

Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-Efficacy, Reflective Thinking, and Critical Thinking: A Structural Equation Modeling Study Among Adolescents. *Islamic Guidance and Counseling Journal*, *8*(2). https://doi.org/10.25217/0020258684000

Pajares, F., & Miller, M. D. (1995). Mathematics Self-Efficacy and Mathematics Performances: The Need for Specificity of Assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022-0167.42.2.190

Paudel, K. C., & Ghimire, S. P. (2024). Mathematics Self-efficacy among Secondary Level Students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130.

Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievementA multilevel analysis of the Programme for International Student Assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014

Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' Mathematical Creative Thinking and Learning Obstacles in Solving Ill-Structured Exponential Problems. *Jurnal Didaktik Matematika*, *12*(1), 53–74. https://doi.org/10.24815/jdm.v12i1.43834

Schunk, D. H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist*, *19*(1), 48–58.

Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033

Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of mathematics self-efficacy and motivation in mathematics performance across ethnicity. *The Journal of Educational Research*, *97*(4), 208–222.

Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? *Psychology, Evaluation, and Technology in Educational Research*, *7*(2), 292–302. https://doi.org/10.33292/petier.v7i2.304

Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How Students' Self-Efficacy Can Affect Their Mathematical Critical Thinking Ability? *(Jiml) Journal of Innovative Mathematics Learning*, *8*(3), 381–387. https://doi.org/10.22460/jiml.v8i3.26650

Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11*. https://doi.org/10.3389/feduc.2026.1696182

Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and

mathematics achievement: multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 1–29. https://doi.org/10.1186/s40536-024-00204-z

Yousuf, M. I., & Rajeswari, G. (2024). Relationship between Mathematics Self Efficacy and Mathematics Achievement. *International Journal of Emerging Knowledge Studies*, *03*(10), 797–802. https://doi.org/10.70333/ijeks-03-10-011

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Yulianto, D., Umami, M. R., & Mony, R. S. (2024a). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yulianto, D., Umami, M. R., & Mony, R. S. (2024b). Fostering critical thinking and self-efficacy in mathematics students. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1). https://doi.org/10.1088/1742-6596/1987/1/012023

Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.986622

Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

4. Artikel jadi dan Publis

Journal of Advanced Sciences and Mathematics Education
Volume 6, Issue 3, 326-350.
e_ISSN: 2798-1606
DOI: 10.58524/jasme.v6i3.1480

Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critical thinking skills: Evidence from structural equation modeling

Nanang Khuzaini* Universitas Mercu Buana, INDONESIA
Nuryadi Universitas Mercu Buana, INDONESIA
Muhammad Irfan Rumasoreng Universitas Mercu Buana, INDONESIA
Muhammad Farid Nasrulloh Universitas Wahab Hasbulloh, INDONESIA
Arie Purwanto Universitas Mercu Buana, INDONESIA

Article Info

Article history:

Received: May 10, 2026
Revised: June 25, 2026
Accepted: Augst 01, 2026

Keywords:

Critical Thinking; Learning Motivation; Mathematical Self-Efficacy; Secondary Mathematics Education; Structural Equation Modeling.

Abstract

Background: Critical thinking is a key competency in mathematics education that enables students to analyze information, justify reasoning, and solve problems effectively. Although learning motivation and mathematical self-efficacy are widely recognized as important affective factors, their comparative contributions to students' critical thinking remain unclear.
Aims: This study aimed to compare the predictive roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills in solving Pythagorean theorem problems.
Method: A quantitative cross-sectional correlational design was employed involving 34 eighth-grade students selected through simple random sampling. Data were collected using an ARCS-based learning motivation questionnaire, a mathematical self-efficacy questionnaire, and an Ennis-based critical thinking test. Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) with LISREL 8.80 were used to evaluate the proposed model.
Results: The measurement model demonstrated satisfactory validity and reliability (KMO = 0.892; factor loadings ≥ 0.50). The refined structural model achieved acceptable fit (NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, RMSEA = 0.093). Mathematical self-efficacy positively predicted critical thinking (t = 4.40), whereas learning motivation showed a significant negative association (t = −2.26).
Conclusion: Mathematical self-efficacy was a stronger predictor of critical thinking than learning motivation, indicating that students' confidence in performing mathematical tasks is more closely associated with higher-order reasoning. Given the limited sample size, these findings should be interpreted as preliminary evidence requiring further validation.

To cite this article: Khuzaini, N., Nuryadi., Rumasoreng, M. I., Nasrulloh, M. F. & Purwanto, A. (2026). Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critical thinking skills: Evidence from structural equation modeling. *Journal of Advanced Sciences and Mathematics Education, 6*(3), 326-350.

INTRODUCTION

Critical thinking has become one of the most essential competencies in mathematics education because students are expected not only to obtain correct answers but also to analyse information, justify solution strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). Such problems require students to understand problem situations, identify relevant mathematical information, establish conceptual relationships, compare alternative solution strategies, and evaluate the validity of their reasoning

***Corresponding author:**
Nanang Khuzaini, Universitas Mercu Buana, Indonesia
nanang@mercubuana-yogya.ac.id

before drawing conclusions. These cognitive processes enable students to construct meaningful mathematical understanding rather than merely applying memorised algorithms. Consequently, critical thinking has become an important learning outcome that supports mathematical reasoning, problem solving, and decision making across diverse mathematical contexts (Sachdeva & Eggen, 2021; Shanta & Wells, 2022; Szabo et al., 2020). Despite its recognised importance, many secondary school students continue to experience difficulties in analysing mathematical problems and explaining the rationale underlying their solutions. Students frequently rely on procedural approaches without adequately evaluating whether their chosen strategies are logically appropriate or mathematically justified. Such tendencies indicate that students often demonstrate procedural proficiency while lacking deeper conceptual and analytical reasoning. As a result, improving students' critical thinking remains one of the major challenges confronting contemporary mathematics education. Therefore, identifying the factors that contribute to students' critical thinking has become an increasingly important concern for mathematics education researchers and practitioners.

The development of students' critical thinking is influenced not only by cognitive competence but also by affective factors that shape how students approach challenging mathematical tasks. Among the affective variables most frequently associated with mathematics learning are learning motivation and mathematical self-efficacy. Learning motivation encourages students to participate actively in classroom activities, maintain persistence during learning, and direct their efforts toward achieving academic goals. Students with higher learning motivation are generally expected to devote greater attention, demonstrate stronger perseverance, and willingly engage with difficult mathematical problems. Such behavioural characteristics are theoretically assumed to facilitate deeper cognitive engagement during mathematical reasoning and problem-solving activities (Chiu et al., 2022; Lyu et al., 2025; Shwartz & Fuchs, 2025; Zou et al., 2025). Nevertheless, empirical findings concerning the relationship between learning motivation and mathematical thinking remain inconsistent across different educational settings. That academic self-motivation demonstrated limited or no significant relationship with secondary school students' mathematical thinking (Alotaibi, 2020). These findings suggest that students' willingness to learn does not necessarily translate into stronger analytical reasoning or higher levels of critical thinking when solving mathematical problems. Consequently, learning motivation may function as an important prerequisite for learning engagement without directly determining students' critical thinking performance. This inconsistency indicates that additional psychological factors should be considered to explain variations in students' mathematical critical thinking.

One psychological factor that has consistently demonstrated a close relationship with mathematical performance is mathematical self-efficacy, which refers to students' beliefs about their capability to successfully perform mathematical tasks (Chan et al., 2022; Pajares & Miller, 1995; Yuliyanto et al., 2021; Zakariya, 2022). Unlike learning motivation, which primarily reflects students' willingness to engage in learning activities, mathematical self-efficacy concerns students' confidence in organising and executing the actions required to solve mathematical problems successfully. Students possessing strong mathematical self-efficacy are generally more willing to attempt challenging tasks, persist after experiencing difficulties, test alternative solution strategies, and interpret mistakes as valuable learning experiences rather than as failures. Conversely, students with low mathematical self-efficacy tend to avoid complex problems, rely heavily on routine procedures, and terminate problem-solving efforts prematurely. Recent studies have also demonstrated that mathematical self-efficacy varies considerably across educational levels and student characteristics, highlighting the importance of strengthening students' confidence in mathematics learning (Paudel & Ghimire, 2024). Previous empirical studies further reported that mathematical self-efficacy contributes significantly to students' mathematical critical thinking and interacts with instructional

approaches implemented in mathematics classrooms (Yulianto et al., 2024). Similarly, found a strong positive relationship between mathematical self-efficacy and students' critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). Collectively, these findings indicate that mathematical self-efficacy functions as an important psychological foundation supporting students' engagement in higher-order mathematical reasoning. However, most previous studies have examined mathematical self-efficacy independently or within particular instructional interventions rather than comparing its predictive contribution with other affective variables within a unified structural model. Therefore, further investigation is required to clarify the comparative role of mathematical self-efficacy relative to learning motivation in explaining students' critical thinking skills.

Several important research gaps remain in the existing literature regarding the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking in mathematics education. First, previous studies have predominantly examined learning motivation and mathematical self-efficacy as independent predictors of mathematical learning outcomes rather than comparing their unique contributions within a unified analytical framework. Studies investigating learning motivation have primarily focused on its relationship with mathematical thinking without simultaneously considering mathematical self-efficacy as a competing predictor, whereas research on mathematical self-efficacy has generally examined its contribution to critical thinking under different instructional contexts without directly comparing its predictive strength with learning motivation (Alotaibi, 2020; Marlena & Nugraheni, 2026; Yulianto et al., 2024). Consequently, existing evidence has not adequately determined whether either construct retains a significant unique contribution after the shared variance between learning motivation and mathematical self-efficacy is statistically controlled. Second, studies that have simultaneously examined learning motivation and mathematical self-efficacy have mainly investigated how instructional interventions improve both constructs rather than evaluating their relative predictive effects on students' critical thinking. More recent theoretical perspectives also suggest that learning motivation functions as an upstream motivational factor, whereas mathematical self-efficacy represents a more proximal determinant of cognitive engagement and mathematical problem solving; however, this proposition has rarely been empirically examined using Structural Equation Modeling (SEM) to explain students' critical thinking (Dai et al., 2025; Ismail et al., 2026; Robinson, 2023). Third, previous studies generally assume that higher learning motivation naturally leads to stronger higher-order thinking while giving limited attention to the possibility that the magnitude or even the direction of its contribution may change after mathematical self-efficacy is incorporated into the same structural model. Fourth, research specifically investigating students' critical thinking in solving Pythagorean theorem problems remains relatively limited, despite the fact that such problems require students to interpret mathematical information, identify conceptual relationships, justify solution strategies, evaluate evidence, and formulate logically defensible conclusions. Moreover, no previous study has explicitly compared the relative predictive contributions of learning motivation and mathematical self-efficacy toward critical thinking within a single structural model, leaving the comparative mechanism underlying these affective factors insufficiently understood. Therefore, this study addresses these theoretical and empirical gaps by simultaneously estimating and comparing the predictive contributions of learning motivation and mathematical self-efficacy to students' critical thinking skills using Structural Equation Modeling, thereby providing a more comprehensive explanation of how these affective constructs influence higher-order mathematical thinking.

Based on the identified research gaps, this study aims to compare the predictive contributions of learning motivation and mathematical self-efficacy to students' critical thinking skills in solving Pythagorean theorem problems using Structural Equation Modeling (SEM). Specifically, the study examines whether learning motivation significantly predicts students' critical

thinking skills in mathematics. The study also investigates whether mathematical self-efficacy significantly predicts students' critical thinking skills when solving mathematical problems. Furthermore, the study compares the relative predictive strength of learning motivation and mathematical self-efficacy when both constructs are simultaneously estimated within a single structural model. Unlike previous studies that have primarily investigated these variables independently, this study adopts a comparative structural perspective to determine which affective construct provides the stronger direct contribution to students' critical thinking. This comparative approach is expected to provide a deeper understanding of the distinct psychological roles of students' willingness to learn and their confidence in performing mathematical tasks. From a theoretical perspective, the findings are expected to enrich the literature on affective factors influencing higher-order thinking by clarifying the comparative mechanism through which learning motivation and mathematical self-efficacy contribute to critical thinking in mathematics education. From a methodological perspective, the application of Structural Equation Modeling enables the simultaneous estimation of relationships among multiple latent constructs, thereby providing a more comprehensive analytical framework than conventional correlational analyses. From a practical perspective, the findings are expected to provide empirical evidence that can assist mathematics teachers in designing instructional strategies that not only enhance students' motivation to learn but also strengthen their confidence in solving complex mathematical problems. Ultimately, this study seeks to contribute to the development of evidence-based mathematics instruction that effectively promotes students' critical thinking and supports the achievement of higher-order learning outcomes in secondary mathematics education.

LITERATURE REVIEW

Critical thinking is widely recognized as one of the fundamental competencies required in mathematics education because it enables students to analyze information systematically, evaluate evidence, justify mathematical reasoning, and formulate logical conclusions when solving problems. Rather than focusing solely on obtaining correct answers, critical thinking emphasizes the quality of reasoning that underlies mathematical decision-making and problem-solving processes. In mathematics learning, critical thinking becomes particularly important when students encounter non-routine problems that require conceptual understanding, strategic planning, and reflective evaluation instead of the direct application of memorized procedures. Students with well-developed critical thinking skills are generally able to identify relevant information (Dulun & Lane, 2023; Li et al., 2020; Okolie et al., 2022; Zlatkin-Troitschanskaia et al., 2020), distinguish assumptions from evidence, compare alternative solution strategies, and evaluate the validity of their conclusions before making mathematical judgments. These cognitive processes promote meaningful learning because students actively construct mathematical knowledge through reasoning rather than passive knowledge acquisition. Conceptualizes critical thinking as reasonable and reflective thinking directed toward deciding what to believe or do, and proposes several dimensions, including elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. These dimensions have been widely adopted in mathematics education research because they comprehensively represent students' analytical, evaluative, and reflective reasoning during mathematical problem solving. Previous empirical studies consistently demonstrate that students with stronger critical thinking skills achieve better mathematical problem-solving performance, conceptual understanding, and reasoning ability than those with lower critical thinking skills (Agusman et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). Consequently, developing students' critical thinking has become one of the primary objectives of contemporary mathematics education and an important indicator of successful mathematics

instruction. Therefore, understanding the psychological factors that facilitate the development of mathematical critical thinking remains an important area of investigation for mathematics education researchers.

Learning motivation represents one of the most influential affective factors shaping students' engagement, persistence, and achievement during mathematics learning. Motivation explains why students are willing to initiate learning activities, sustain effort when encountering difficulties, and continue pursuing academic goals despite experiencing challenges. Motivational model conceptualizes learning motivation as consisting of four interrelated dimensions, namely attention, relevance, confidence, and satisfaction, which collectively influence students' willingness to participate actively in learning activities. The attention dimension emphasizes students' ability to maintain interest throughout learning, whereas relevance concerns the perceived usefulness and meaningfulness of learning activities for achieving personal goals. Confidence reflects students' expectations of successfully completing learning tasks, while satisfaction represents the positive feelings that arise after accomplishing learning objectives. Within mathematics education, motivated students generally demonstrate greater classroom participation, invest more cognitive effort, employ more effective learning strategies, and persist longer when solving complex mathematical problems (Granello et al., 2026; Kitsantas et al., 2021; Lugosi & Uribe, 2022; Supriadi et al., 2024; Zuo et al., 2024). Such behavioral characteristics are theoretically expected to promote deeper cognitive processing and ultimately improve higher-order thinking skills, including mathematical critical thinking. Nevertheless, empirical evidence regarding the relationship between learning motivation and mathematical critical thinking remains inconsistent across different educational contexts. Some studies report that learning motivation positively predicts mathematical reasoning and academic achievement, whereas other findings suggest that motivation alone is insufficient to explain students' mathematical thinking after other psychological variables are considered (Alotaibi, 2020). These inconsistencies indicate that learning motivation should be examined together with other affective constructs to obtain a more comprehensive explanation of students' critical thinking performance in mathematics.

Mathematical self-efficacy represents students' beliefs about their capability to organize and execute the actions required to successfully complete mathematical tasks and solve mathematical problems. According to Social Cognitive Theory, self-efficacy influences how individuals think, feel, behave, and persist when confronted with challenging situations because confidence in one's capability determines the amount of effort and perseverance invested in task completion (Kitsantas et al., 2021; Meng & Zhang, 2023; Namono et al., 2024; Schunk & DiBenedetto, 2021). In mathematics education, mathematical self-efficacy extends beyond general academic confidence by specifically reflecting students' beliefs regarding their competence in understanding mathematical concepts, applying mathematical procedures, and solving unfamiliar mathematical problems. Bandura conceptualized self-efficacy through three dimensions, namely level, strength, and generality, which describe individuals' confidence across varying task difficulties, the intensity of their confidence, and the transferability of their confidence across different situations. Students possessing high mathematical self-efficacy are generally more willing to attempt challenging problems, sustain their effort despite repeated failures, regulate their learning strategies, and interpret mistakes as opportunities for improvement rather than indicators of inability. Conversely, students with low mathematical self-efficacy often avoid cognitively demanding tasks, experience greater mathematics anxiety, and rely on routine procedures without exploring alternative solution strategies. Numerous empirical studies have consistently reported that mathematical self-efficacy positively predicts mathematics achievement, conceptual understanding, mathematical reasoning, and problem-solving performance across different educational levels (Chan et al., 2022; Paudel & Ghimire, 2024; Yuliyanto et al., 2021; Zakariya, 2022). Recent evidence also indicates that mathematical self-efficacy

contributes significantly to students' mathematical critical thinking because confident learners are more likely to engage in analytical reasoning, evaluate evidence critically, and justify their mathematical decisions when solving complex problems (Marlena & Nugraheni, 2026; Yulianto et al., 2024). These findings suggest that mathematical self-efficacy functions as a proximal psychological mechanism linking students' beliefs about their mathematical capability with their ability to perform higher-order cognitive processes during mathematical learning. Therefore, mathematical self-efficacy has become one of the most influential affective constructs for explaining individual differences in students' mathematical critical thinking and higher-order reasoning.

Learning motivation and mathematical self-efficacy are conceptually related because both influence students' engagement and persistence during mathematics learning, yet they represent different psychological mechanisms underlying learning behavior. Learning motivation primarily explains why students are willing to participate in learning activities, whereas mathematical self-efficacy determines whether students believe they possess the capability to successfully complete mathematical tasks and overcome learning difficulties (Abdulla & Ibrahim, 2023; Peng & Fu, 2021; Raes et al., 2020; Zhu et al., 2020). Social Cognitive Theory proposes that self-efficacy functions as a more proximal determinant of cognitive performance because students' confidence directly influences their strategic thinking, self-regulation, persistence, and decision-making during problem solving. In contrast, learning motivation serves as an antecedent that encourages students to initiate learning activities but does not necessarily ensure successful cognitive performance when students lack confidence in their mathematical abilities. Previous studies have generally reported positive associations between learning motivation, mathematical self-efficacy, and mathematics achievement, although the relative contribution of each construct to critical thinking remains inconclusive (Alotaibi, 2020; Marlena & Nugraheni, 2026; Yulianto et al., 2024). Several intervention studies further demonstrated that instructional approaches designed to improve motivation often simultaneously strengthen students' mathematical self-efficacy, indicating substantial conceptual overlap between these affective constructs. Nevertheless, the majority of existing studies have focused on examining the independent effects of motivation or self-efficacy rather than comparing their predictive contributions within a single structural model. Consequently, it remains unclear whether learning motivation continues to exert a meaningful influence on students' critical thinking after the contribution of mathematical self-efficacy has been statistically controlled. Addressing this issue is important because distinguishing the relative roles of these two affective constructs may provide a more accurate theoretical explanation of how students develop higher-order mathematical thinking. Accordingly, the present study employs Structural Equation Modeling (SEM) to simultaneously estimate and compare the predictive contributions of learning motivation and mathematical self-efficacy toward students' critical thinking, thereby providing a stronger theoretical foundation for improving mathematics instruction and fostering higher-order thinking skills.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas

students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participant

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected using a simple random sampling technique. Each student in the population was assigned an identification number, and the participants were selected using a computer-generated random-number procedure, ensuring that every student had an equal probability of being included in the study. All selected students agreed to participate, completed the research procedures, and provided complete datasets; therefore, no participants were excluded from the final analysis. Prior to data collection, permission to conduct the study was obtained from the school administration. Written informed consent was obtained from the students' parents or legal guardians, and assent was obtained from all participating students. The participants were informed about the objectives of the study, and participation was entirely voluntary. According to the institutional policy, formal ethics committee approval was not required for this educational research involving minimal risk. All collected data were treated confidentially and used solely for research purposes.

Instrument

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, comprising four dimensions: Attention, Relevance, Confidence, and Satisfaction. The instrument consisted of [insert number] items, each rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of learning motivation. Representative items included "I pay close attention during mathematics lessons" (Attention), "The mathematics lessons are relevant to my daily life" (Relevance), "I am confident that I can successfully complete mathematics tasks" (Confidence), and "I feel satisfied after successfully solving mathematics problems" (Satisfaction). Negatively worded items, if any, were reverse-coded prior to data analysis so that higher scores consistently reflected higher learning motivation. The instrument was adapted from Keller's ARCS motivational framework and demonstrated good internal consistency, with a Cronbach's alpha/Construct Reliability (CR) of [insert value] in the present study. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework (Bandura, 2006). The instrument measured three dimensions of mathematical self-efficacy: Level, Strength, and Generality, reflecting students' confidence in performing mathematical tasks with varying levels of complexity, persistence in overcoming mathematical difficulties, and the transferability of their confidence across different mathematical situations. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of mathematical self-efficacy. The instrument was translated and adapted to the Indonesian junior high school context and was reviewed by mathematics education experts to ensure linguistic clarity, cultural appropriateness, and content validity prior to administration.The instrument measured three dimensions:

a. Level; b. Strength; c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks specifically related to the Pythagorean Theorem with varying levels of complexity. The items were designed to assess students' beliefs in their capability to understand Pythagorean concepts, select appropriate solution strategies, solve contextual Pythagorean problems, and justify their mathematical reasoning. This domain-specific approach is consistent with Bandura's recommendation that self-efficacy should be measured as closely as possible to the target performance domain in order to enhance its predictive validity.

Critical Thinking Test

Students' critical thinking skills were assessed using an essay-based mathematics test developed within the context of the Pythagorean Theorem. The instrument was constructed based on Ennis' critical thinking framework and measured five dimensions: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The test consisted of essay problems requiring students to analyse contextual mathematical situations, identify relevant information, justify their solution strategies, perform mathematical reasoning, and explain the validity of their conclusions. Students completed the test during the allocated instructional period under teacher supervision. Responses were evaluated using an analytic scoring rubric aligned with the five critical thinking dimensions proposed by Ennis, with higher scores indicating higher levels of critical thinking performance. To ensure scoring consistency, all responses were assessed independently by two mathematics education lecturers using the same scoring rubric. Any discrepancies in scoring were resolved through discussion until consensus was reached. Prior to implementation, both the instrument and the scoring rubric were reviewed by mathematics education experts to establish content validity.The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:

a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

Prior to implementation, all research instruments were subjected to expert judgment to establish content validity. The validation process involved three experts in mathematics education, each holding a doctoral degree and having extensive experience in mathematics teaching, educational assessment, and instrument development. The experts evaluated the instruments in terms of content relevance, construct representation, language clarity, readability, and suitability for junior high school students. The degree of agreement among the experts was quantified using Aiken's V, and all items achieved values above the recommended threshold for acceptable content validity. Based on the experts' recommendations, several items were revised to improve wording, clarity, and alignment with the intended constructs before the instruments were administered in the main study.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, the underlying statistical assumptions were evaluated. The assessment indicated that the data satisfied the

assumptions required for Structural Equation Modeling. Multivariate normality was examined using LISREL, and the results indicated that the data did not exhibit substantial departures from multivariate normality. Multicollinearity was assessed by examining the correlations among the latent constructs as well as the tolerance and Variance Inflation Factor (VIF) values. The results showed no evidence of problematic multicollinearity, with all tolerance values exceeding 0.10 and all VIF values remaining below the recommended threshold of 10. In addition, tests of linearity and homogeneity confirmed that the data met the assumptions necessary for SEM analysis. These findings indicate that the estimated structural relationships were not adversely affected by violations of the underlying statistical assumptions and that the proposed model was appropriate for subsequent hypothesis
testing.

The measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50. The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual (SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values. Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 (α = 0.05). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

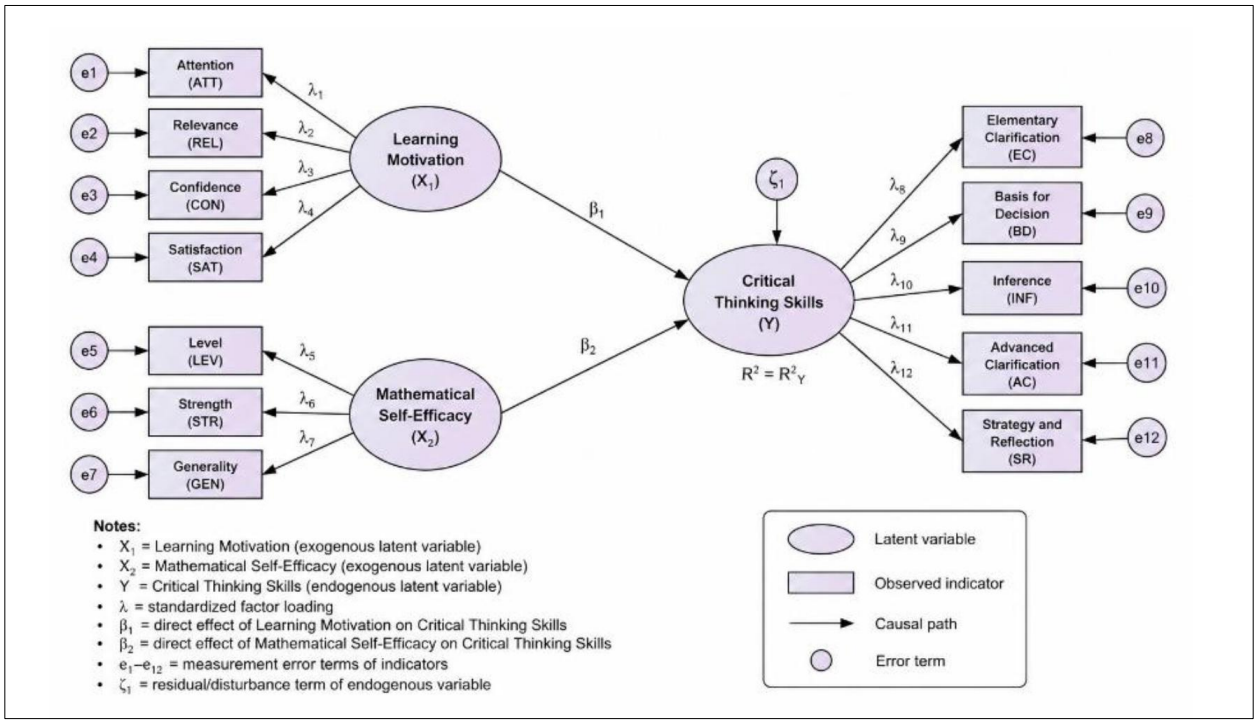


Figure 1. Proposed structural equation model of the study.

RESULTS AND DISCUSSION

Results

Preliminary Analysis

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis. The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test Value	Test Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result ($\chi^2 = 1307.307$, $df = 66$, $p < 0.001$), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis. Overall, the KMO measure and Bartlett's Test indicate that the data were suitable for factor analysis and provided an appropriate basis for conducting Confirmatory Factor Analysis (CFA). However, the adequacy of the measurement model was primarily established through the CFA results, including standardized factor loadings, construct reliability, and convergent validity, which collectively demonstrated that the proposed measurement model was acceptable for subsequent structural model analysis. Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model. Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

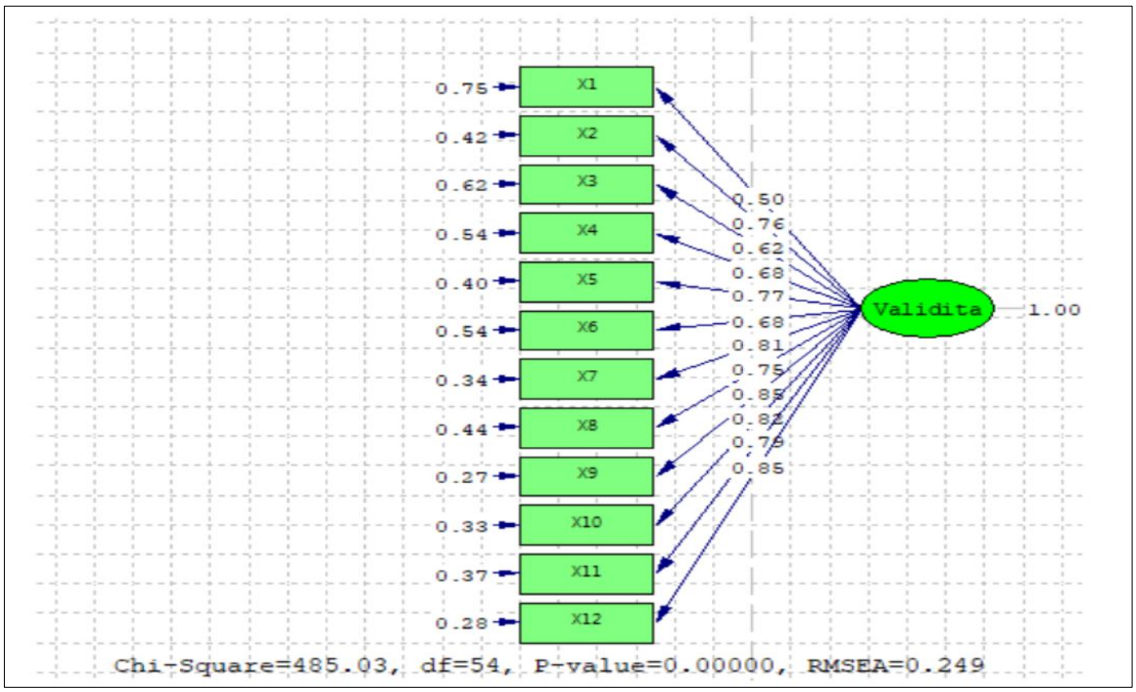


Figure 2. CFA Test

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34

Indikator	Loading (λ)	Error Variance (ε)
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Construct Reliability (CR):

$$CR = \frac{(\sum\lambda)2}{(\sum\lambda)2 + \sum\varepsilon}$$

Calculation results:

$\sum\lambda$ = 8,58
$(\sum\lambda)2$ = 73,62
$\sum\varepsilon$ = 5,30

so that

$$CR = \frac{73,62}{73,62 + 5,30} = 0,933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.
Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum\lambda2}{\text{n}}$$

Sum of squared loadings

$\sum\lambda2$ = 6,70

With n = 12

So

$$AVE = \frac{6,70}{12} = 0,558$$

The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity. In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). Construct validity was evaluated using standardized factor loadings for each latent construct, whereas construct reliability was assessed separately for Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking Skills using Composite Reliability (CR) and Average Variance Extracted (AVE). The results demonstrated satisfactory internal consistency and convergent validity for all three constructs, with CR values exceeding the recommended threshold of 0.70 and AVE values exceeding 0.50, indicating that each construct exhibited adequate reliability and explained more than half of the variance of its respective indicators. The construct-specific CR and AVE values are presented in Table 3.

Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs

employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Tabel 3. Construct Reliability and Convergent Validity of Each Latent Construct

Construct	Number of Indicators	Composite Reliability (CR)	Average Variance Extracted (AVE)	Interpretation
Learning Motivation	4	**0.738**	**0.418**	Reliable; convergent validity below the recommended threshold
Mathematical Self-Efficacy	3	**0.800**	**0.572**	Reliable and convergently valid
Critical Thinking Skills	5	**0.907**	**0.662**	Highly reliable and convergently valid

Structural Model Evaluation

After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data. The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI = 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, the measurement model was re-specified based on the Modification Indices (MI) generated by LISREL. Model refinement was limited to correlating measurement error terms between indicators belonging to the same latent construct when supported by both the Modification Indices and theoretical considerations. Specifically, residual correlations were added between eX2–eX3 (Learning Motivation), eY1–eY2 (Mathematical Self-Efficacy), and eZ2–eZ3 (Critical Thinking), as these indicator pairs measured closely related aspects of the same construct and shared similar wording and conceptual content. The corresponding Modification Indices exceeded the recommended threshold (MI > 3.84), indicating that correlating these residuals would substantially improve model fit. No cross-construct residual correlations or additional structural paths were introduced, thereby preserving the theoretical structure of the proposed model. Following these theoretically justified modifications, the goodness-of-fit indices improved substantially (NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, RMSEA = 0.093), indicating that the revised model provided a better representation of the observed data. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. Most goodness-of-fit indices satisfied the recommended criteria, indicating that the revised model achieved an acceptable overall fit. The incremental fit indices demonstrated good model fit (NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94), whereas the RMSEA value (0.093) indicated a marginal but still acceptable level of approximation. Collectively, these results suggest that the revised structural model provides an adequate representation of the observed data and is appropriate for subsequent hypothesis testing,

with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement. The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

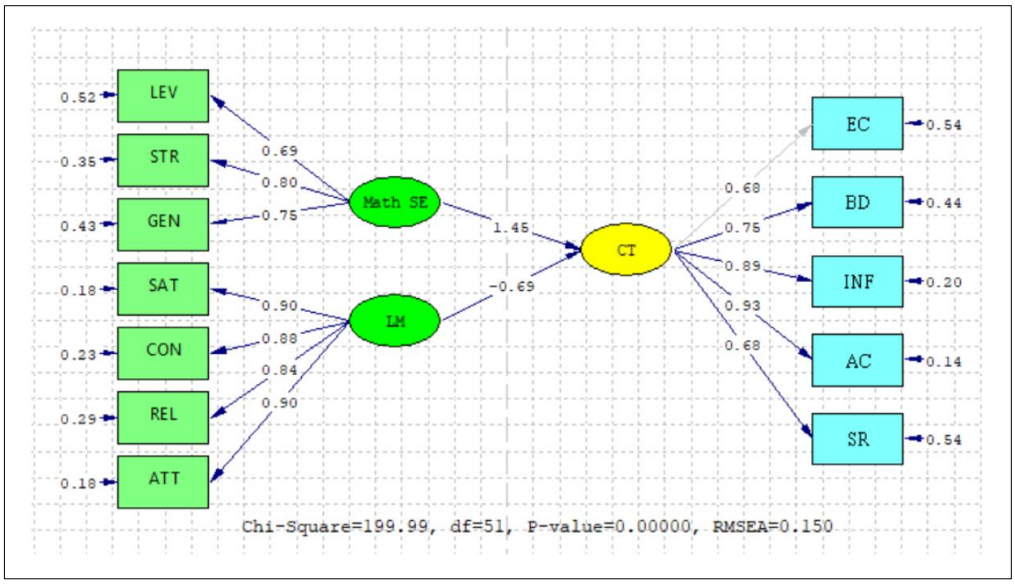
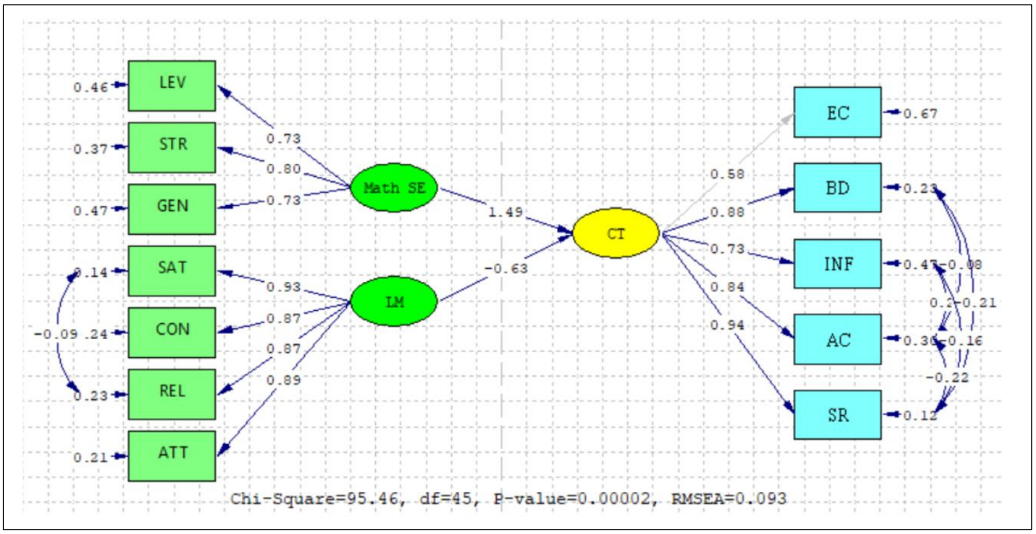


Figure 3. Model SEM

Tabel 4. Goodness-of-Fit model

No	Goodness-of-Fit Index	Cut-off Value	Value	Decision
1	NNFI	≥ 0.90	0.88	Not Good
2	GFI	≥ 0.90	0.88	Not Good
3	NFI	≥ 0.90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good
5	RMSEA	≤ 0.08	0.150	Not Good



Figuer 4. Re-analysis of the SEM Model

Tabel 5. Reanalisis Goodness-of-Fit model

No	Goodness-of-Fit Index	Cut-off Value	Value	Decision
1	NNFI	≥ 0.90	0.97	Good
2	CFI	≥ 0.90	0.98	Good
3	NFI	≥ 0.90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≤ 0.08	0.093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero. As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value (|−2.26| = 2.26) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction. These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the structural relationships were interpreted based on both the statistical significance and the direction of the estimated path coefficients. The results indicated that the effect of Mathematical Self-Efficacy on Critical Thinking Skills was statistically significant and consistent with the hypothesised positive direction, thereby supporting the proposed hypothesis. In contrast, although the effect of Learning Motivation on Critical Thinking Skills was statistically significant, the estimated coefficient was negative rather than positive. Consequently, this relationship cannot be considered supportive of the original directional hypothesis and should instead be interpreted as evidence of a statistically significant inverse association within the present sample.

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level. As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Table X presents the structural parameter estimates obtained using the Maximum Likelihood estimation procedure in LISREL 8.80. Mathematical Self-Efficacy had a positive and statistically significant effect on Critical Thinking Skills (B = 1.25, SE = 0.29, t = 4.40, $p < 0.001$), indicating that higher levels of mathematical self-efficacy were associated with higher levels of critical thinking. In contrast, Learning Motivation showed a statistically significant negative effect on Critical Thinking Skills (B = −0.53, SE = 0.23, t = −2.26, p = 0.024). Although statistically significant, the direction of the

coefficient was opposite to the hypothesised positive relationship; therefore, the hypothesis regarding the positive effect of Learning Motivation was not supported. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

Table 6. Structural Path Estimates

Structural Path	Unstandardized Coefficient (B)	Standard Error (SE)	*t*-value	*p*-value	Decision
Learning Motivation → Critical Thinking	-0.53	0.23	-2.26	0.024	Significant, but hypothesis not supported
Mathematical Self-Efficacy → Critical Thinking	1.25	0.29	4.40	< 0.001	Supported

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold (|−2.26| > 1.96), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy. Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

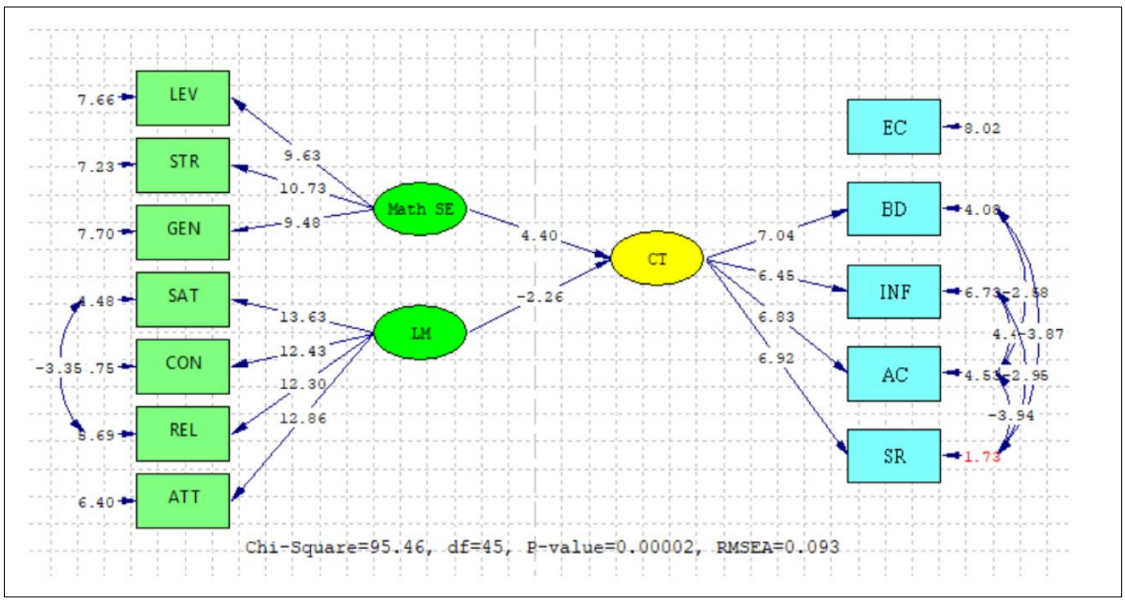


Figure 5. t-value Model SEM

Discussion

The findings demonstrate that the proposed structural model provides an acceptable representation of the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. Following model refinement, the goodness-of-fit indices improved substantially, with NNFI, CFI, NFI, and RFI all exceeding the recommended threshold, while the RMSEA value decreased from 0.150 to 0.093, indicating a considerable reduction in model misfit. Although the RMSEA value remained slightly above the conventional criterion for a close-fitting model, values below 0.10 are generally considered indicative of an acceptable or marginal fit for exploratory structural models, particularly when the sample size is relatively limited. These findings suggest that the revised structural model is sufficiently robust to explain the

hypothesized relationships among the latent constructs despite the inherent limitations of the dataset. The acceptable fit achieved after model refinement also indicates that the theoretical assumptions underlying the proposed model are largely consistent with the observed empirical relationships. More importantly, the results support the proposition that students' critical thinking skills are shaped not only by cognitive competence but also by affective characteristics that influence how students approach, regulate, and persist in solving mathematical problems. This finding is consistent with contemporary perspectives in mathematics education, which argue that higher-order thinking develops through the interaction between cognitive processes and motivational or self-regulatory factors rather than through conceptual knowledge alone (Tay et al., 2024; Tee et al., 2021; Wu et al., 2026). Consequently, understanding students' affective characteristics becomes essential for explaining variations in mathematical reasoning and critical thinking beyond differences in academic ability. The present findings therefore reinforce the growing recognition that mathematics learning should be viewed as an integrated cognitive-affective process in which psychological variables substantially influence students' reasoning performance. Within this framework, the proposed Structural Equation Modeling (SEM) provides a comprehensive analytical approach for simultaneously examining the complex relationships among multiple affective constructs and their contributions to students' critical thinking skills.

The measurement model further demonstrated that learning motivation was effectively represented by the four dimensions of the ARCS framework, namely attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. The high loading values indicate that all four dimensions consistently captured students' motivational characteristics and collectively provided a reliable representation of the latent construct. Among these dimensions, attention and satisfaction emerged as the strongest indicators, suggesting that students' motivation was primarily reflected in their sustained engagement during mathematics learning and the positive feelings experienced after successfully completing learning activities. This finding implies that students' motivation is strengthened not merely through external encouragement but also through meaningful learning experiences that foster curiosity, active engagement, and a sense of accomplishment (Daniel et al., 2024; Hellín et al., 2023; Owens et al., 2020). The prominence of the attention and satisfaction dimensions supports the theoretical proposition that sustained engagement and positive learning experiences are fundamental components in maintaining students' motivation throughout the learning process. Although the confidence dimension also demonstrated a relatively high loading, it should be distinguished conceptually from mathematical self-efficacy because it represents students' general expectations of success during learning rather than their beliefs regarding their capability to perform specific mathematical tasks successfully. This distinction is particularly important because the conceptual similarity between the confidence dimension of the ARCS model and mathematical self-efficacy may create overlapping variance when both constructs are simultaneously estimated within the same structural model. Such conceptual overlap provides a plausible explanation for why the contribution of learning motivation changed after mathematical self-efficacy was incorporated into the structural model. Similar findings have been reported in previous studies showing that instructional approaches capable of enhancing learning motivation frequently strengthen mathematical self-efficacy simultaneously (Huang et al., 2020; Zakariya, 2022), thereby making the empirical separation of these constructs increasingly challenging during multivariate analyses. Therefore, the present findings suggest that learning motivation should not be interpreted as an entirely independent psychological determinant of critical thinking but rather as an affective construct whose contribution is closely intertwined with students' confidence in their mathematical capabilities.

Mathematical self-efficacy emerged as a significant positive predictor of students' critical thinking skills, indicating that students who possessed stronger confidence in their mathematical

capabilities demonstrated better higher-order reasoning when solving Pythagorean theorem problems. The positive structural coefficient and significant t-value indicate that students' beliefs regarding their capability to perform mathematical tasks contributed directly to their ability to analyse information, evaluate evidence, justify solution strategies, and formulate logical conclusions. This finding supports the proposition of Social Cognitive Theory, which argues that individuals' beliefs about their capabilities influence not only their behavioral persistence but also their cognitive engagement and performance during challenging tasks. Students with high mathematical self-efficacy are generally more willing to attempt unfamiliar mathematical problems, sustain effort after experiencing difficulties, evaluate alternative strategies, and regulate their own learning processes (Liu et al., 2025; Street et al., 2022). Such behaviours create favourable conditions for the development of critical thinking because students remain cognitively engaged throughout the problem-solving process instead of avoiding challenging situations. The present findings are consistent with previous studies demonstrating that mathematical self-efficacy contributes significantly to students' mathematical critical thinking and higher-order reasoning across different instructional settings (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). Similar evidence has also been reported in large-scale educational studies showing that mathematical self-efficacy consistently predicts mathematics achievement even after controlling for individual and school characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these findings indicate that mathematical self-efficacy functions as a proximal psychological determinant that directly supports students' analytical reasoning and critical thinking during mathematical problem solving. The present study therefore extends previous research by demonstrating that mathematical self-efficacy remains the strongest predictor of critical thinking even when learning motivation is estimated simultaneously within the same structural model. These findings reinforce the importance of strengthening students' mathematical confidence as an integral component of instructional practices aimed at improving higher-order thinking in mathematics education.

The measurement model further revealed that the strength dimension represented the strongest indicator of mathematical self-efficacy, followed by generality and level, suggesting that students' confidence was primarily reflected in their persistence when facing mathematical challenges rather than merely in their willingness to undertake tasks with different levels of difficulty. This finding implies that perseverance in confronting complex mathematical problems constitutes a more influential psychological characteristic than confidence associated solely with task difficulty (DiNapoli, 2023; Gabriel et al., 2020; Jiang et al., 2021; Voica et al., 2020; Zuo et al., 2024). Critical thinking rarely develops through immediate success because students are typically required to analyse information, evaluate evidence, revise incorrect assumptions, compare alternative strategies, and continuously reflect on the appropriateness of their reasoning before reaching valid conclusions. Under such circumstances, students with stronger self-beliefs are more likely to remain engaged in cognitive processing despite experiencing temporary failure or uncertainty. Conversely, students with weaker mathematical self-efficacy may discontinue problem-solving efforts prematurely because they perceive mathematical challenges as exceeding their capabilities. The relatively lower loading of the level dimension further indicates that students' confidence tends to decline as mathematical tasks become increasingly complex, even though they may still demonstrate persistence throughout the learning process. This pattern suggests that instructional practices should not only encourage students to participate actively in mathematics learning but should also provide graduated mastery experiences that progressively strengthen their confidence across varying levels of task difficulty. Previous intervention studies have likewise demonstrated that instructional approaches emphasizing guided practice, collaborative problem solving, constructive feedback, and authentic mastery experiences effectively strengthen students'

mathematical self-efficacy while simultaneously improving higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Sudiartini et al., 2025). Therefore, the present findings provide additional empirical evidence that strengthening students' persistence and confidence represents an effective pedagogical strategy for promoting critical thinking in mathematics classrooms. Taken together, these results support the view that mathematical self-efficacy should be regarded not merely as a positive personal belief but as a strategic psychological resource that enables students to sustain cognitive engagement throughout complex mathematical reasoning and critical problem-solving activities.

The findings of this study provide important theoretical and pedagogical implications by clarifying the distinct roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills in mathematics. The results indicate that mathematical self-efficacy functions as a more proximal psychological determinant of higher-order thinking, whereas learning motivation primarily initiates students' engagement in learning activities before cognitive processes are activated. This distinction supports the perspective of Social Cognitive Theory, which emphasizes that students' beliefs about their capabilities directly influence cognitive engagement, persistence, and performance during challenging learning tasks. Consequently, the development of students' critical thinking should be understood as the outcome of interactions between motivational processes and beliefs about mathematical competence rather than as the product of learning motivation alone. From a pedagogical perspective, mathematics instruction should extend beyond fostering students' interest in learning by systematically strengthening their mathematical self-efficacy through authentic mastery experiences, graduated instructional support, constructive feedback, collaborative learning, and reflective problem-solving activities. Such instructional practices are expected to improve not only students' confidence but also their analytical reasoning, metacognitive regulation, and persistence when solving complex mathematical problems. These implications are consistent with previous studies demonstrating that contextual and problem-based learning simultaneously enhance mathematical self-efficacy and critical thinking by providing meaningful opportunities for reasoning and reflection (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024). Nevertheless, the findings should be interpreted cautiously because the relatively small sample size and the presence of a standardized coefficient exceeding the recommended threshold suggest the possibility of suppression effects or multicollinearity within the structural model. Future studies involving larger and more diverse samples are therefore needed to validate the stability of the proposed model and examine whether the observed relationships remain consistent across different mathematical topics and educational contexts. Overall, this study contributes to the growing body of mathematics education research by providing empirical evidence that strengthening students' mathematical self-efficacy represents a more effective pathway for fostering critical thinking than focusing solely on increasing learning motivation.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently. Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self- efficacy. Teachers are encouraged to design

learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting its findings. First, the study involved a relatively small sample from a single junior high school, which limits the generalizability of the results to broader educational contexts. Second, the research focused exclusively on the Pythagorean theorem, and the identified structural relationships may differ when applied to other mathematical topics with different cognitive characteristics. Third, the cross-sectional design only captures relationships among variables at one point in time and therefore does not explain causal or developmental changes in students' critical thinking. In addition, although the structural model achieved acceptable goodness-of-fit, there is still room for improving the model by refining its specification and incorporating additional explanatory variables. Future studies are encouraged to involve larger and more diverse samples from different educational levels and school settings to improve the robustness and generalizability of the findings. Longitudinal or experimental research designs are also recommended to examine the causal development of critical thinking and the long-term influence of mathematical self-efficacy and learning motivation. Furthermore, future research should incorporate additional psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, and classroom learning environment, to develop a more comprehensive explanatory model. Alternative analytical approaches may also be considered to validate the consistency and stability of the proposed structural relationships. From a practical perspective, mathematics teachers should design learning experiences that emphasize meaningful problem solving, guided practice, reflective activities, and constructive feedback to strengthen students' mathematical self-efficacy. Such instructional strategies are expected to enhance students' confidence while simultaneously fostering stronger critical thinking skills and more effective mathematical reasoning.

CONCLUSION

This study investigated the structural relationships among learning motivation, mathematical self- efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using. Structural Equation Modeling (SEM). Overall, the measurement model demonstrated generally acceptable psychometric properties. The results indicated adequate sampling adequacy and satisfactory construct reliability across the three latent constructs. Convergent validity was fully supported for the Mathematical Self-Efficacy and Critical Thinking constructs, whereas the Learning. Motivation construct exhibited acceptable reliability but a slightly lower Average Variance Extracted (AVE) than the recommended threshold. Considering the relatively small sample size and the model re-specification based on theoretically justified modification indices, these findings should be interpreted with appropriate caution. Nevertheless, the measurement model provides sufficient empirical support for subsequent structural model analysis. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data. The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence,

analytical reasoning, and reflective thinking when confronting complex mathematical tasks. The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

AUTHOR CONTRIBUTIONS STATEMENT

Nanang Khuzaini contributed to the conceptualization of the study, research design, instrument development, data collection, data analysis using Structural Equation Modeling (SEM), interpretation of the findings, and manuscript drafting. Nuryadi contributed to the methodological framework, statistical analysis, interpretation of the SEM results, and critical revision of the manuscript. Muhammad Irfan Rumasoreng contributed to the theoretical framework, validation of the research instruments, interpretation of the findings, and manuscript review. Muhammad Farid Nasrulloh contributed to data validation, literature review, interpretation of the results, and manuscript editing. Arie Purwanto contributed to research supervision, methodological guidance, critical review of the manuscript, and final approval of the version to be published. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

REFERENCES

Abdulla, H. M., & Ibrahim, M. A. (2023). The impact of urban spatial plan on land value: An approach system to relating space syntax premises to the land price. *Sustainability*, *15(9).* https://doi.org/10.3390/su15097239

Agusman, A., Purwanto, P., & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the relationship between academic self-motivation and the mathematical thinking: A case study of secondary school students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the impact of discovery learning and self-efficacy on students' critical thinking skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4), 5950–5961. https://doi.org/10.35445/alishlah.v17i4.7134

Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking: A social cognitive approach in Japanese junior high schools. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807

Cahyani, V. F., & Setyaningsih, R. (2024). The implementation of problem-based learning to enhance critical thinking skills in solving contextual mathematics problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29

Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement model and adaptation of self-efficacy toward mathematics reasoning among university students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114

Chiu, M.-S., Lin, F.-L., Yang, K.-L., Hasumi, T., Wu, T.-J., & Lin, P.-S. (2022). The interplay of affect and cognition in the mathematics grounding activity: Forming an affective teaching model. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), em2187. https://doi.org/10.29333/ejmste/12579

Dai, L., Jin, W., Zhu, B., Liao, R., Xu, G., Jiang, H., & Guan, J. (2025). Exploring the role of social media in mathematics learning: Effects on self-efficacy, interest, and self-regulation. *BMC Psychology*, *13*(1), 829. https://doi.org/10.1186/s40359–025–03192-z

Daniel, K., Msambwa, M. M., Antony, F., & Wan, X. (2024). Motivate students for better academic achievement: A systematic review of blended innovative teaching and its impact on learning. *Computer Applications in Engineering Education*, *32*(4), e22733. https://doi.org/10.1002/cae.22733

DiNapoli, J. (2023). Distinguishing between grit, persistence, and perseverance for learning mathematics with understanding. *Education Sciences*, *13(4).* https://doi.org/10.3390/educsci13040402

Dulun, Ö., & Lane, J. F. (2023). Supporting critical thinking skills needed for the International Baccalaureate Diploma Programme: A content analysis of a national and two international education programs in Turkey. *Thinking Skills and Creativity*, *47*, 101211. https://doi.org/10.1016/j.tsc.2022.101211

Gabriel, F., Buckley, S., & Barthakur, A. (2020). The impact of mathematics anxiety on self-regulated learning and mathematical literacy. *Australian Journal of Education*, *64*(3), 227–242. https://doi.org/10.1177/0004944120947881

Granello, F., Cuder, A., Doz, E., Pellizzoni, S., & Passolunghi, M. C. (2026). "I can do math!": A self-regulated learning intervention to enhance math-related motivational factors and performance in middle school. *British Journal of Educational Psychology*, *96*(2), 501–521. https://doi.org/10.1111/bjep.70034

Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007

Hellín, C. J., Calles-Esteban, F., Valledor, A., Gómez, J., Otón-Tortosa, S., & Tayebi, A. (2023). Enhancing student motivation and engagement through a gamified learning environment. *Sustainability*, *15(19).* https://doi.org/10.3390/su151914119

Huang, X., Mayer, R. E., & Usher, E. L. (2020). Better together: Effects of four self-efficacy-building strategies on online statistical learning. *Contemporary Educational Psychology*, *63*, 101924. https://doi.org/10.1016/j.cedpsych.2020.101924

Ismail, I., Jamaluddin, A. B., Muis, A., Pratiwi, A. C., Palennari, M., & Adnan, A. (2026). Cultivating innovation readiness in biology education: The mediating roles of plant attitudes and scientific argumentation in deep learning and cognitive flexibility. *Qubahan Academic Journal*, *6*(2), 157–176. https://doi.org/10.48161/qaj.v6n2a2429

Jiang, R., Liu, R., Star, J., Zhen, R., Wang, J., Hong, W., Jiang, S., Sun, Y., & Fu, X. (2021). How mathematics anxiety affects students' inflexible perseverance in mathematics problem-solving: Examining the mediating role of cognitive reflection. *British Journal of Educational Psychology*, *91*(1), e12364. https://doi.org/10.1111/bjep.12364

Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1), 2394738. https://doi.org/10.1080/2331186X.2024.2394738

Kitsantas, A., Cleary, T. J., Whitehead, A., & Cheema, J. (2021). Relations among classroom context, student motivation, and mathematics literacy: A social cognitive perspective. *Metacognition and Learning*, *16*(2), 255–273. https://doi.org/10.1007/s11409–020–09249–1

Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140

Li, Y., Li, X., Zhu, D., & Guo, H. (2020). Cultivation of the students' critical thinking ability in numerical control machining course based on the virtual simulation system teaching method. *IEEE Access*, *8*, 173584–173598. https://doi.org/10.1109/ACCESS.2020.3025079

Liu, Z., Guo, H., Zhou, Z., Ma, F., & Zeng, Y. (2025). How creative self-efficacy influences problem-solving skills in engineering education: The dual mediating role of critical thinking and metacognition. *BMC Psychology*, *13*(1), 1278. https://doi.org/10.1186/s40359–025–03630-y

Lugosi, E., & Uribe, G. (2022). Active learning strategies with positive effects on students' achievements in undergraduate mathematics education. *International Journal of Mathematical Education in Science and Technology*, *53*(2), 403–424. https://doi.org/10.1080/0020739X.2020.1773555

Lyu, B., Li, C., Li, H., & Xing, W. (2025). The effects of text-based conversational teachable agents' communicative features on student math learning: Tone style and emoji use. *Journal of Research on Technology in Education*, *0*(0), 1–23. https://doi.org/10.1080/15391523.2025.2511313

Marlena, L., & Nugraheni, E. A. (2026). The correlation between self-efficacy and critical thinking skills of senior high school students on the Pythagorean Theorem material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587

Masitoh, L. F., & Fitriyani, H. (2018). Improving students mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30. https://doi.org/10.29103/mjml.v1i1.679

Meng, Q., & Zhang, Q. (2023). The influence of academic self-efficacy on university students' academic performance: The mediating effect of academic engagement. *Sustainability*, *15(7).* https://doi.org/10.3390/su15075767

Namono, R., Hojops, O. J. P., & Tanui, S. (2024). Self-efficacy: Implications for university employees' innovativeness. *International Journal of Innovation Science*, *17*(5), 1235–1252. https://doi.org/10.1108/IJIS-05–2023–0106

Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-efficacy, reflective thinking, and critical thinking: A structural equation modeling study among adolescents. *Islamic Guidance and Counseling Journal*, *8(2).* https://doi.org/10.25217/0020258684000

Okolie, U. C., Igwe, P. A., Mong, I. K., Nwosu, H. E., Kanu, C., & Ojemuyide, C. C. (2022). Enhancing students' critical thinking skills through engagement with innovative pedagogical practices in Global South. *Higher Education Research & Development*, *41*(4), 1184–1198. https://doi.org/10.1080/07294360.2021.1896482

Owens, D. C., Sadler, T. D., Barlow, A. T., & Smith-Walters, C. (2020). Student motivation from and resistance to active learning rooted in essential science practices. *Research in Science Education*, *50*(1), 253–277. https://doi.org/10.1007/s11165–017–9688–1

Pajares, F., & Miller, M. D. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity of assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022–0167.42.2.190

Paudel, K. C., & Ghimire, S. P. (2024). Mathematics self-efficacy among secondary level students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130. https://doi.org/10.3126/pragyaratna.v6i1.64544

Peng, R., & Fu, R. (2021). The effect of Chinese EFL students' learning motivation on learning outcomes within a blended learning environment. *Australasian Journal of Educational Technology*, *37*(6), 61–74. https://doi.org/10.14742/ajet.6235

Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the programme for international student assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014

Raes, A., Vanneste, P., Pieters, M., Windey, I., Van Den Noortgate, W., & Depaepe, F. (2020). Learning and instruction in the hybrid virtual classroom: An investigation of students' engagement and the effect of quizzes. *Computers & Education*, *143*, 103682. https://doi.org/10.1016/j.compedu.2019.103682

Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' mathematical creative thinking and learning obstacles in solving ill-structured exponential problems. *Jurnal Didaktik Matematika*, *12*(1), 53–74. https://doi.org/10.24815/jdm.v12i1.43834

Robinson, K. A. (2023). Motivational climate theory: Disentangling definitions and roles of classroom motivational support, climate, and microclimates. *Educational Psychologist*, *58*(2), 92–110. https://doi.org/10.1080/00461520.2023.2198011

Sachdeva, S., & Eggen, P.-O. (2021). Learners' critical thinking about learning mathematics. *International Electronic Journal of Mathematics Education*, *16*(3), em0644. https://doi.org/10.29333/iejme/11003

Schunk, D. H., & DiBenedetto, M. K. (2021). Self-regulation, self-efficacy, and learning disabilities. In S. Misciagna (Ed.), *Learning disabilities—Neurobiology, assessment, clinical features and treatments*. IntechOpen. https://doi.org/10.5772/intechopen.99570

Shanta, S., & Wells, J. G. (2022). Zzprot9zz design based learning: Assessing student critical thinking and problem solving abilities. *International Journal of Technology and Design Education*, *32*(1), 267–285. https://doi.org/10.1007/s10798–020–09608–8

Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033

Shwartz, H., & Fuchs, A. (2025). The cognitive distinctions between mathematical problem-solving and problem-posing processes. *Gaia*, *1*(1), 37.

Street, K. E. S., Malmberg, L.-E., & Stylianides, G. J. (2022). Changes in students' self-efficacy when learning a new topic in mathematics: A micro-longitudinal study. *Educational Studies in Mathematics*, *111*(3), 515–541. https://doi.org/10.1007/s10649–022–10165–1

Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? psychology, evaluation, and technology in educational research, 7(2), 292–302. https://doi.org/10.33292/petier.v7i2.304

Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How students' self-efficacy can affect their mathematical critical thinking ability? (jiml) journal of innovative mathematics learning, 8(3), 503–509. https://doi.org/10.22460/jiml.v8i3.26650

Supriadi, N., Jamaluddin Z, W., & Suherman, S. (2024). The role of learning anxiety and mathematical reasoning as predictor of promoting learning motivation: The mediating role of mathematical problem solving. *Thinking Skills and Creativity*, *52*, 101497. https://doi.org/10.1016/j.tsc.2024.101497

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, *12(23).* https://doi.org/10.3390/su122310113

Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11.* https://doi.org/10.3389/feduc.2026.1696182

Tay, L. Y., Chan, M., Chong, S. K., Tan, J. Y., & Aiyoob, T. B. (2024). Learning of mathematics: A metacognitive experiences perspective. *International Journal of Science and Mathematics Education*, *22*(3), 561–583. https://doi.org/10.1007/s10763–023–10385–8

Tee, K. N., Leong, K. E., & Abdul Rahim, S. S. (2021). A self-regulation model of mathematics achievement for eleventh-grade students. *International Journal of Science and Mathematics Education*, *19*(3), 619–637. https://doi.org/10.1007/s10763–020–10076–8

Voica, C., Singer, F. M., & Stan, E. (2020). How are motivation and self-efficacy interacting in problem-solving and problem-posing? educational studies in mathematics, 105(3), 487–517. https://doi.org/10.1007/s10649–020–10005–0

Wu, M., Liu, Y., Guo, J., & Talib, O. (2026). Why does feedback work? unpacking the serial mediation of emotion regulation and discourse skills in mathematics. *Frontiers in Psychology*, *17.* https://doi.org/10.3389/fpsyg.2026.1854668

Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: Multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 16. https://doi.org/10.1186/s40536–024–00204-z

Yulianto, D., Umami, M. R., & Mony, R. S. (2024). Fostering critical thinking and self-efficacy in mathematics students: Exploring the impact of contextual learning and problem-based learning as well as direct instruction. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1), 012023. https://doi.org/10.1088/1742–6596/1987/1/012023

Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13.* https://doi.org/10.3389/fpsyg.2022.986622

Zhu, Y., Zhang, J. H., Au, W., & Yates, G. (2020). University students' online learning attitudes and continuous intention to undertake online courses: A self-regulated learning perspective. *Educational Technology Research and Development*, *68*(3), 1485–1519. https://doi.org/10.1007/s11423–020–09753-w

Zlatkin-Troitschanskaia, O., Beck, K., Fischer, J., Braunheim, D., Schmidt, S., & Shavelson, R. J. (2020). The role of students' beliefs when critically reasoning from multiple contradictory sources of information in performance assessments. *Frontiers in Psychology*, *11.* https://doi.org/10.3389/fpsyg.2020.02192

Zou, L., Zhang, Z., Mavilidi, M., Chen, Y., Herold, F., Ouwehand, K., & Paas, F. (2025). The synergy of embodied cognition and cognitive load theory for optimized learning. *Nature Human Behaviour*, *9*(5), 877–885. https://doi.org/10.1038/s41562–025–02152–2

Zuo, S., Huang, Q., & Qi, C. (2024). The relationship between cognitive activation and mathematics achievement: Mediating roles of self-efficacy and mathematics anxiety. *Current Psychology*, *43*(39), 30794–30805. https://doi.org/10.1007/s12144–024–06700–3