From Mathematics and Science Literacy to Future STEM Talent: A Conceptual Framework for Malaysia in the Post-PISA 2025 Context

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ABSTRACT

Malaysia's Programme for International Student Assessment (PISA) 2025 results highlight concerns about foundational mathematics and science literacy, but cross-sectional assessment scores cannot predict students' later educational or career outcomes. This conceptual paper develops the Mathematics-Science-STEM Pathway (MSSP) Framework to explain how literacy may relate to readiness for advanced subjects, self-efficacy and interest, Science, Technology, Engineering, and Mathematics (STEM) identity, educational choices and persistence, career preparation, and the specialised workforce. A narrative literature search and conceptual synthesis bring together official assessment and policy evidence, Social Cognitive Career Theory (SCCT), longitudinal and review research, and Malaysian studies. The framework proposes seven testable relationships across educational stages and distinguishes individual pathways from aggregate national capability. It identifies psychological mechanisms and contextual conditions, including teaching, course access, socioeconomic resources, family support and STEM exposure, that may influence transitions. Alternative entry and re-entry routes recognise that progression is neither uniform nor irreversible. Organisation for Economic Co-operation and Development (OECD) figures show that 35% of Malaysian students attained at least Level 2 in mathematics and 54% in science in 2025; mathematics performance was lower than in 2022. These results motivate inquiry but do not demonstrate downstream effects. The framework offers a structured agenda for Malaysian longitudinal and multilevel research and for interventions that evaluate both competence and opportunities to progress into STEM.

Keywords: PISA 2025, mathematics literacy, science literacy, STEM career, human capital

INTRODUCTION

STEM talent development begins before tertiary education. Mathematics and science learning can support quantitative reasoning, evidence evaluation, and progression to more demanding subjects, while educational opportunities and students' beliefs influence whether they use those capabilities. This paper examines the links between these stages in Malaysia without equating an international assessment score with a later career outcome.

Mathematical reasoning underpins many branches of science, engineering and computing. Science learning develops the ability to interpret evidence and evaluate explanations. The distinction between demonstrated achievement and perceived competence matters: students with similar performance may make different

choices when they anticipate different benefits, costs or prospects of success.

The latest PISA results provide an important context for examining these foundations. PISA assesses the extent to which 15-year-old students can apply knowledge and skills to complex problems and real-world situations [1]. Table 1 summarises Malaysia's reported PISA scores from 2009 to 2025. The historical record fluctuates mathematics rose from 404 in the 2009 cycle to 440 in 2018, then fell to 409 in 2022 and 397 in 2025 [1]. The 2015 values are shown for historical completeness but are excluded from OECD trend comparisons because they did not meet sampling-response standards. Compared with 2018, Malaysia's mean performance in 2025 was lower in all three PISA domains. The OECD reports that the proportion below Level 2 rose by 24 percentage points in mathematics and by ten percentage points in each of reading and science [1]. In 2025, 35% attained at least Level 2 in mathematics and 54% in science, compared with OECD averages of 65% and 74%. These are population-level proficiency indicators; they do not measure readiness for a particular upper-secondary course or predict individual STEM careers.

Table 1. Malaysia's PISA mean scores across all participation cycles, 2009–2025

PISA Cycle	Mathematics	Reading	Science	Key Observation
2009	404	414	422	Malaysia's first PISA cycle; testing took place in 2010
2012	421	398	420	Mathematics increased; reading declined; science remained broadly similar
2015*	446	431	443	Higher reported scores across all three domains
2018	440	415	438	Strong performance relative to Malaysia's other reported cycles
2022	409	388	416	Decline from 2018 across all three domains
2025	397	393	419	Mathematics declined further; reading and science were broadly stable from 2022

Sources: OECD PISA 2025 country note [1] and Malaysia Education Blueprint Annual Report 2016 [2]. Malaysia joined the cycle labelled PISA 2009 through a 2010 assessment. *The 2015 figures are included as nationally reported historical data. The OECD excludes Malaysia's 2015 results from trend comparisons because sampling-response standards were not met; the 2015 row must not be used to infer a comparable 2015-to-2018 change.

The gap between foundational literacy and later STEM outcomes requires explanation. Longitudinal and review evidence associates educational choices with achievement, interest, anxiety, self-efficacy, identity and contextual support [3,4,5,6,7]. Malaysian studies report related motivational and social factors [8,9,10]. These bodies of evidence inform possible mechanisms, although none establishes that Malaysian PISA performance causes later workforce shortages. PISA therefore raises a question about the conditions under which students can develop the preparation and confidence to engage in advanced mathematics and science. The analysis treats students who score below a proficiency threshold as learners who may benefit from support, not as students unable to pursue STEM. Moving from school learning to a STEM occupation involves separate transitions: access to advanced subjects, course achievement, confidence and interest, programme entry, persistence and employment. Each transition can be shaped by earlier learning and by new opportunities. The MSSP framework specifies these stages so that they can be studied independently and in combination.

Malaysia's labour-market evidence makes this question relevant. The World Bank identifies shortages in specific engineering, ICT and applied technical occupations, including software, data and cybersecurity roles, while noting that the share of STEM-related graduates has been broadly flat since 2015 [11]. These

observations indicate occupational mismatch and limits in the training pipeline; they do not show that PISA performance caused the shortages. The article's contribution is a framework that connects these otherwise separate assessment, educational and workforce discussions through explicitly provisional relationships. This concern is timely in the context of Malaysia's education policy. The Rancangan Pendidikan Malaysia (RPM) 2026–2035 identifies seven strategic thrusts and 49 initiatives spanning curriculum, student talent, educator professionalism, infrastructure, stakeholder collaboration and governance [12]. The Rancangan Pendidikan Tinggi Malaysia (RPTM) 2026–2035 addresses the subsequent transition into higher education and future skills [13]. These documents establish policy relevance for examining continuity from school mathematics and science to later STEM education; they do not themselves demonstrate the causal relationships proposed in this paper. This paper develops the MSSP framework, defines its constructs, formulates seven propositions, and indicates how to assess them in Malaysian longitudinal and multilevel studies. It separates student-level development from aggregate workforce and innovation outcomes.

CONCEPTUAL METHOD AND LITERATURE FOUNDATION

This article uses a narrative literature search followed by conceptual synthesis. Relevant publications were identified mainly through Google Scholar, with theoretical and international evidence prioritising studies indexed in Scopus and Web of Science and published in high-impact, peer-reviewed journals, while Malaysian-context studies were drawn from indexed regional and national journals to ensure local relevance, and selected for their contribution to the proposed MSSP framework. The evidence base comprises research on

mathematics and science learning, advanced-subject participation, STEM self-efficacy, interest and identity, and educational and career transitions, alongside OECD assessment reports and Malaysian education and labour-market documents. Sources published up to September 2026 were retained when they directly informed a construct, proposed relationship, theoretical mechanism or Malaysian contextual condition. We retained foundational theory regardless of publication year, and prioritised recent longitudinal studies, reviews, and primary institutional documents where available. The manuscript does not report a reproducible database search, screening count or quality appraisal; accordingly, it makes no claim of exhaustive coverage.

The synthesis first distinguished student-level literacy, achievement, psychological beliefs, choices and persistence from aggregate workforce outcomes. It then mapped empirical findings and SCCT concepts to the proposed transitions and examined whether Malaysian studies and official reports provided context-specific support. Finally, it formulated propositions with candidate indicators and potential mediators or moderators (Table 2). A reported association is treated as evidence for plausibility, not proof of the proposed causal sequence. The synthesis describes the purpose and rationale for selecting sources; without a documented search log, completeness cannot be evaluated.

SCCT explains the central transition from learning experience to educational and career choice. Its original formulation relates learning experiences to self-efficacy and outcome expectations, then to interests, goals, actions and persistence, while contextual supports and barriers affect opportunities [14]. The MSSP framework uses this mechanism to propose that competence and subsequent learning experiences may be associated with confidence and interest. Expectancy-value research also emphasises perceived value and costs when students choose STEM options [7], while physics-identity research shows how recognition, interest, and classroom experiences relate to disciplinary identity [6]. These theories illuminate student-level mechanisms; neither directly predicts national workforce capacity.

The framework does not assume an irreversible or uniform sequence. Students can enter STEM through academic, technical or later educational routes, leave a programme and return through further training. Additional learning can strengthen competence and self-efficacy after an initial setback. The arrows in Figure 1 therefore indicate proposed relationships and possible feedback, rather than a single compulsory route.

CONCEPTUAL FRAMEWORK AND PROPOSITIONS

The terms in the framework serve different purposes. Literacy denotes the application of mathematics and science knowledge in unfamiliar contexts, as assessed by PISA; achievement denotes a measured result on a specified assessment. Competence is a broader set of knowledge and skills, and readiness is preparation for more demanding study. Self-efficacy refers to a student's belief in their ability to perform specified tasks, whereas STEM identity concerns seeing oneself, and being recognised, as a participant in STEM [6,14]. Career readiness concerns preparation for an occupational transition; national capability is an aggregate property shaped by the workforce and institutions. These constructs should be measured separately.

Mathematics and Science Literacy as Foundational STEM Competencies

Mathematics and science literacy constitute the first component of the proposed framework. PISA defines competency in ways that emphasise students' capacity to reason, apply knowledge, interpret evidence, and solve problems in real-world contexts [1]. Thus, PISA performance should not be interpreted simply as mastery of school examination content. These competencies are particularly relevant to STEM because advanced STEM learning increasingly requires students to transfer knowledge rather than merely reproduce procedures. Mathematical modelling, quantitative reasoning, scientific interpretation, and evidence-based problem solving underpin numerous STEM disciplines. Consequently, persistent weaknesses in mathematics and science literacy may reduce the strength of the academic foundation upon which subsequent STEM learning is built. This does not imply that students performing below a particular PISA proficiency level are incapable of pursuing STEM. Instead, it suggests that a weaker foundational competency base may increase the difficulty of later progression unless appropriate educational support is provided. The mathematics trend deserves particular attention. Malaysia's mean mathematics performance fell from 440 in 2018 to 409 in 2022 and 397 in 2025 [1]. The latest OECD evidence therefore indicates that mathematics has not demonstrated the same relative stabilisation between 2022 and 2025 observed in science and reading.

P1: Higher mathematics and science literacy is expected to be associated with greater readiness for advanced mathematics and pure science study. This proposed upstream relationship can be tested using earlier assessments and subsequent subject performance, while accounting for prior attainment and access to instruction.

Readiness for Advanced Mathematics and Pure Sciences

The transition from foundational mathematics and science to advanced mathematics and pure science represents a critical stage in the proposed framework. Advanced STEM subjects are cumulative. Students studying physics, chemistry, mathematics, computer science, statistics, engineering, and related disciplines progressively encounter greater abstraction, mathematical representation, quantitative reasoning, and multi-stage problem solving. Difficulties that are manageable at earlier educational stages may therefore become increasingly consequential when academic demands increase. Malaysia has historically recognised the importance of developing a strong science base. The Malaysia Education Blueprint documented the longstanding aspiration for greater science participation at upper-secondary level and noted that science-stream enrolment had previously fallen from a high of 37% in 1998 to 29% in 2012, with perceived subject difficulty identified as one possible contributor [15]. However, academic ability alone does not determine whether students continue with mathematics and science. Students interpret their experiences psychologically. Repeated difficulty may affect confidence, enjoyment, perceived competence, and perceptions of whether STEM is appropriate for them.

P2: The association between foundational competence and later subject participation is expected to be partly mediated by readiness for advanced study and perceived ability to succeed. School support and access to appropriate courses may moderate this transition.

Mathematics and Science Competence, Self-Efficacy, Interest and STEM Identity

A key contribution of the proposed framework is its inclusion of psychological mechanisms between academic competence and STEM participation. A study analysed self-reports from 7,908 participants at ages

16, 18 and 21 [3]. Mathematics interest during adolescence predicted later STEM career choice after accounting for other measured factors. Mathematics self-efficacy did not independently predict career choice when examined jointly with interest and anxiety. This distinction cautions against treating all motivational constructs as equivalent or assuming that each has a direct effect. A systematic review identified self-motivation, social persuasion, self-efficacy, perceived utility and positive STEM experiences among influences reported across studies of aspirations and choices [4]. These findings support a multidimensional framework, while differences in study design limit causal interpretation. A meta-analysis links STEM identity with career intention [5]. Work on physics identity further connects recognition, interest and classroom experiences with how students view their place in a specific discipline [6]. Identity may therefore be both a proposed mediator of participation and an outcome strengthened by positive participation; longitudinal data are needed to distinguish these directions. A student with adequate academic preparation may still opt out of STEM if its perceived value is low or its anticipated cost is high [7]. Conversely, access to supportive teaching and bridging routes may help a student with weaker initial preparation persist. These examples motivate propositions about interactions between competence, beliefs and context; they are not universal predictions about individuals.

P3: The proposed relationship between competence and STEM educational progression is expected to operate partly through self-efficacy, interest and STEM identity. The strength and ordering of these mechanisms require longitudinal testing rather than inference from PISA scores alone.

From STEM Interest to Educational Choice and Persistence

Interest must subsequently be translated into educational behaviour. STEM career choices develop through interactions among individual and contextual factors. The systematic review indicates that interest and self-efficacy operate alongside family influences, perceived utility, positive experiences, and broader social conditions [4]. Malaysian evidence supports this multidimensional interpretation. The study of 419 Form Four students in Malaysia reported a substantial relationship between motivation towards science learning and interest in STEM-related careers. Their structural-equation analysis indicated that science motivation accounted for substantial variation in STEM career interest [8]. The Malaysian review [9] identifies social, motivational and learning-context themes rather than a single determinant. Together with SCCT [14], this evidence motivates testing whether supports and barriers affect subject selection directly, moderate the link between interest and action, or shape earlier learning opportunities. These alternatives should remain analytically distinct. A simple chain from achievement to occupation would overlook selection, resources and repeated learning. The framework therefore allows both mediated and reciprocal relationships: competence may precede confidence and choice, while continued participation may further develop competence and identity [6,7,14].

P4: Among students with comparable academic preparation, stronger STEM self-efficacy, interest and identity are expected to predict subsequent STEM subject choice and persistence. Family, teacher and peer support, as well as opportunities for STEM exposure, may strengthen or weaken these associations.

Stem Education and Career Readiness

Participation in STEM education represents an important bridge between school-level competencies and workforce development. STEM career readiness requires more than subject knowledge. Students need opportunities to apply scientific and mathematical reasoning, develop problem-solving capabilities, understand potential STEM occupations, and recognise the relevance of their education to future employment. The contemporary literature suggests that career aspirations are formed well before entry into employment. Students' experiences during adolescence shape how they evaluate STEM occupations and whether they regard these careers as desirable and attainable [4]. Among 377 Malaysian B40 pre-university graduates already studying STEM majors, Abd Rauf and Hashim [10] reported associations of self-efficacy and perceptions of STEM careers with satisfaction in STEM study. Because the sample excludes non-STEM majors, the study cannot establish whether these factors influence entry into a STEM field. Thus, the educational challenge is not simply attracting students into STEM programmes but supporting them throughout a sequence of increasingly demanding transitions.

P5: Participation and persistence in advanced school and tertiary STEM learning are expected to increase career-related knowledge and preparation for STEM work. This proposition can be examined through subject enrolment, programme retention, qualifications and career-readiness measures across successive transitions.

From Stem Careers to National Human Capital

The implications of STEM education become broader when educational pathways are considered in relation to national labour-market needs. The World Bank [11] identifies shortages in engineering, software development, data and cybersecurity, engineering technology and digital manufacturing, and interprets them as specific occupational mismatches rather than an overall shortage of graduates. The share of graduates in STEM-related fields has remained broadly flat since 2015. These labour-market observations indicate a need to examine field-specific preparation, skill quality and absorption into employment. This distinction is crucial. Malaysia may produce increasing numbers of tertiary graduates while still experiencing shortages in specific high-skilled STEM areas if graduates' educational composition and competencies do not align with emerging economic requirements. TalentCorp's MyCOL 2024/2025 [16] lists several engineering and other technical occupations among critical occupations. The list documents employer-reported demand; it should not be presented as direct evidence of the educational origin of those shortages. Thus, the educational question connects to a broader human-capital question: Can Malaysia develop a sufficiently large and capable pool of young people who are academically prepared, motivated, and willing to progress from school mathematics and science into advanced STEM education and ultimately into high-skilled STEM occupations?

P6: At the aggregate level, sustained and inclusive STEM educational pathways are expected to enlarge the pool of specialised talent, conditional on training quality, completion and alignment with occupational demand. Individual student pathways cannot by themselves establish a national workforce effect.

Stem Human Capital and Malaysia's Future Capability

The final stage of the framework concerns national capability. Human capital in mathematics, science, engineering, computing, and technology contributes to a country's ability to undertake research, absorb new technologies, innovate, improve production processes, and develop technologically sophisticated industries. These capabilities become increasingly significant as economies encounter artificial intelligence, automation, advanced manufacturing, digitalisation, and emerging technologies. The concern therefore should not be framed as low PISA scores causing Malaysia's economy to decline. Such a conclusion would exceed what existing evidence can establish. Instead, the conceptual argument is that persistent weaknesses in foundational mathematics and science competencies may create upstream vulnerabilities that, when combined with motivational, educational, socioeconomic, and institutional barriers, can reduce the pool of students progressing towards advanced STEM education and specialised STEM occupations. The evidence thus supports the existence of specialised skills gaps [11,16] but does not identify a contribution from PISA achievement to those gaps. P7 is deliberately framed as a separate macro-level hypothesis that would require additional economic and sectoral data.

P7: A larger and appropriately skilled STEM workforce may contribute to technological adoption and innovation capacity, alongside investment, institutions and labour-market conditions. This macro-level proposition requires sectoral and longitudinal evidence and is not an inference from PISA performance.

Table 2. Candidate measures and tests for the MSSP propositions.

Link	**Candidate measures**	**Suggested test**
P1: literacy → advanced readiness	Earlier mathematics and science assessments; later advanced-subject performance	Cohort association adjusted for prior attainment and instruction

P2: competence → participation	Competence; study readiness; perceived ability; course access and enrolment	Mediation by readiness; moderation by course access
P3: competence → beliefs → progression	Competence; self-efficacy; interest; identity; later choices	Repeated-measures mediation and reciprocal models
P4: beliefs → choice and persistence	Beliefs; subject enrolment and retention; family and school support	Prospective associations and moderation by support
P5: STEM study → career preparation	Subject completion; applied skills; career knowledge and readiness	Cohort follow-up across school and tertiary transitions
P6: pathways → specialised workforce	Field-specific completion; training quality; occupational demand	Aggregated cohort trends by field and labour demand
P7: workforce → national capability	Skilled workforce; technology adoption; innovation; investment	Separate sectoral longitudinal models with economic controls

Proposed Mathematics-Science-Stem Pathway Framework

Based on the preceding literature, this paper proposes the Mathematics-Science-STEM Pathway (MSSP) Framework. Contextual factors operate at multiple transitions: teacher quality, pedagogy, curriculum and school resources can shape learning and readiness; socioeconomic background, parental and peer support, gender-related experiences and digital access can influence opportunities and beliefs; STEM exposure, guidance and institutional entry routes can affect participation and re-entry. Figure 1 represents proposed relationships rather than verified causal effects. Contextual conditions can affect learning, advanced-course access and educational choices at several points. The dashed return route represents additional learning and re-entry after a change of direction; it does not imply that all students follow the same path. Table 2 converts each proposition into an empirical question.

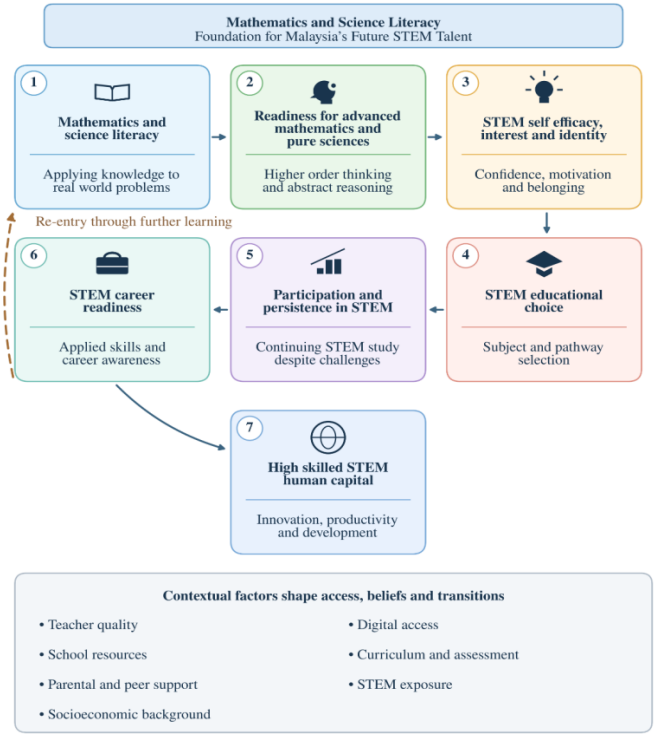


Figure 1. Proposed Mathematics-Science-STEM Pathway (MSSP) Framework for Malaysia.

Source: Authors' conceptual synthesis of the cited research; SCCT mechanisms informed by Lent et al. [14].

DISCUSSION

The MSSP framework interprets PISA 2025 as an indicator of foundational learning in a wider educational context. OECD data show that Malaysia's mathematics performance fell while reading and science were broadly stable relative to 2022 [1]. The framework asks how competence, opportunity and motivation might jointly shape later STEM participation, while recognising that a cross-sectional assessment cannot establish any student's future pathway. The marked increase since 2018 in the share of Malaysian students below mathematics proficiency Level 2 warrants attention [1]. Later study in quantitative STEM disciplines may require sustained reasoning and problem-solving support, but the size and causal direction of any downstream effect must be established in cohort data. SCCT offers a way to examine the middle transitions: learning experiences may inform self-efficacy and outcome expectations, while interest, identity and contextual supports can shape choices and persistence [4,5,14]. The figure makes these mechanisms visible so that educational interventions can be evaluated beyond test-score change. Future tests should link prior attainment to later course access and achievement, measure interest and self-efficacy separately, and model reciprocal changes where repeated measures exist. Cohort data could examine mediation by beliefs, moderation by resources, and alternative routes into STEM. Aggregate workforce analyses would require distinct sectoral evidence; student-level associations should not be scaled up automatically. The framework's practical value lies in locating where support can be offered or evaluated: early learning, transition to advanced subjects, development of belonging and interest, programme persistence, and later bridging or re-entry. The most useful policy measure may differ across students and disciplines.

IMPLICATIONS AND RECOMMENDATIONS

At school level, responses to PISA 2025 should prioritise mathematical and scientific reasoning, conceptual understanding and application. Schools can identify learning needs early and offer sustained support, while evaluating progress using more than a single assessment score. At student level, interventions can combine academic support with meaningful STEM experiences, mentoring and career information. Their effects on confidence, interest, identity and later participation should be assessed rather than assumed [3,4,14]. At system level, course availability, subject prerequisites, technical routes, bridging opportunities and tertiary guidance should be aligned so that students can move into or return to STEM study. This is particularly relevant where access and resources differ between schools. At national level, education and workforce agencies can monitor both skills development and specialised occupational demand. The World Bank's discussion of skills mismatch and high-value skills illustrates the need to examine training quality and labour-market absorption as well as the number of graduates [11].

CONCLUSION

PISA 2025 provides a timely measure of mathematics and science literacy among Malaysian 15-year-olds. OECD evidence indicates a further decline in mathematics performance since 2022 and a larger share of students below the baseline proficiency level than in 2018 [1]. These observations motivate, but do not prove, the longer educational relationships advanced here. The MSSP framework proposes links from foundational literacy to advanced-study readiness, psychological mechanisms, educational participation, career preparation and aggregate STEM capability. SCCT explains the connections between learning experiences, beliefs, interests and choices; institutional and socioeconomic conditions shape the opportunities through which those choices can be realised [14]. Its principal contribution is a set of seven testable propositions that distinguish individual educational transitions from national workforce outcomes and permit alternative entry and feedback routes. Longitudinal Malaysian evidence is needed to determine which proposed links hold, for whom and under what conditions. For policy, the framework points to sustained academic support, access to advanced subjects, constructive STEM experiences and flexible progression routes. These measures can be evaluated against competence, participation and persistence outcomes before drawing conclusions about workforce effects. Strengthening foundational learning and widening viable pathways into STEM are therefore connected educational priorities. Whether they lead to a larger and better-matched Malaysian STEM workforce remains an empirical question for future research.

LIMITATION OF THE CONCEPTUAL PAPER

The proposed relationships are conceptual and have not been established as causal pathways for Malaysia. PISA measures a cross-section of 15-year-olds and cannot track their subsequent programmes or careers. The narrative literature search did not involve a recorded exhaustive search or formal study-quality assessment, so relevant studies may have been omitted. The propositions require transparent empirical tests before claims about effects are warranted. Evidence from other countries may not transfer directly to Malaysia. Malaysian studies used here are mainly cross-sectional or review-based; longitudinal links among assessed competence, subject choice, tertiary persistence and employment remain limited. National policy and labour-market documents provide context, not independent tests of the proposed individual-level mechanisms. STEM fields differ in prerequisites and entry routes. Results should be tested by discipline and by socioeconomic background, gender and school context. Aggregated PISA and workforce indicators describe different populations and periods; directly correlating them would risk ecological inference. Future studies could follow Malaysian cohorts from secondary school through advanced-subject choice, tertiary entry, persistence, and early employment, with repeated measures of competence, self-efficacy, interest, identity, and access. Separately, sector-level analyses could test whether the composition and quality of STEM graduates are associated with technological uptake after accounting for investment and labour demand.

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