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A Mixed-Methods Study of School Students as Trendsetters on Co-Designing 3D-Printed Kits for Interdisciplinary STEM Education

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ABSTRACT

Secondary students in Malaysia turn away from STEM partly because the curriculum content is abstract and disconnected from real life. This mixed-methods study evaluated a Student-as-Trendsetter framework in which 10 gifted students codesigned 3D-printed STEM kits and mentored 88 peers. The classroom participants highly rated the peer-led sessions (M = 4.14–4.57), including the trendsetters' expertise (M = 4.35). The trendsetters' self-rated technical competency decreased significantly after the project (from 4.30–4.90 to 1.80–3.00; p < .001). Reflective journals showed that this decline was a healthy recalibration: moving from digital design to physical fabrication exposed real engineering constraints and built grounded, resilient confidence. The framework offers a low-cost route to engaging in student-led STEM learning.

Keywords: 3D printing, gifted students, mixed methods, peer mentoring, STEM education, student as trendsetter

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INTRODUCTION

Educational systems worldwide are increasingly focused on equipping students with practical, real-world skills. In a global job market rapidly transformed by technological shifts and economic demands, this hands-on preparation is critical for preparing graduates to succeed. This level of readiness is vital as graduates transition into a diverse global labor market, which is increasingly defined by changing technological evolution and dynamic economic demand. Ultimately, to develop a successful global career, young professionals must look beyond traditional textbooks. They have to develop a well-rounded toolkit that couples technical expertise with strong communication skills, adaptability and modern STEM training. This framework plays a vital role in workforce readiness while simultaneously advancing sustainable human capacity development (Deming & Noray, 2020; Foi & Kean, 2022; Kayan-Fadlelmula et al., 2022). Moreover, the Malaysian government is focused on preparing youth for the global workforce by elevating national STEM education to meet international standards (Saat & Fadzil, 2022). This commitment is a cornerstone of the Malaysia Education Blueprint 2013–2025 and continues in the Malaysia Education Blueprint 2026–2030, which explicitly aims to strike a balance by maintaining a 60:40 enrollment ratio between science and technical fields and the arts (Abu Hassan et al., 2025). This initiative focuses on strengthening STEM education by increasing student interest in STEM subjects while increasing teachers' confidence and delivery in the classroom (Foi & Kean, 2022; Ministry of Education Malaysia, 2026). According to the Malaysia Education Blueprint, the decline in the number of students enrolled in STEM is primarily due to a lack of interest among secondary school pupils. This is largely due to limited awareness and low exposure to STEM subjects in secondary schools. The lack of support from school leaders, time constraints, heavy workloads, insufficient budgets, and inadequate facilities also contribute to teachers' performance. Teachers find the science syllabus to be heavy and complex, and interdisciplinary STEM education faces significant challenges because of educators' need for more integrated exposure and training (Foi & Kean, 2022; Ministry of Education Malaysia, 2026; Palpanadan & Ravana, 2022). Similar tensions have been reported beyond schools: Humanities academics who designed an interdisciplinary STEM subject described both advantages and challenges in integrating unfamiliar disciplinary knowledge into their teaching (Dawkins & Naidu, 2026). As a result, educators' knowledge and skills need to be updated quickly to keep up with advancements in STEM education (Hisyam et al., 2019; Kayan-Fadlelmula et al., 2022; Shahali et al., 2017).

In modern learning frameworks, core concepts emphasize design thinking and project-based learning, where both activities foster creativity among students, which also catalyze engagement and critical thinking (Bhardwaj et al., 2025; Kakarla, 2024; Valquaresma, 2024). In STEM education specifically, the interdisciplinary connections among blended STEM fields require creativity through hands-on design tasks. Students learn to apply abstract concepts to real-world challenges (Kakarla, 2024; Tabassum et al., 2024). These creative tasks encourage the exploration of "what-if" scenarios, allowing students to see the relevance of their learning beyond textbooks (Jin et al., 2024; Pokhrel, 2022). This hands-on style of learning directly supports global educational movements focused on fostering innovation, digital literacy, and sustainable thinking.

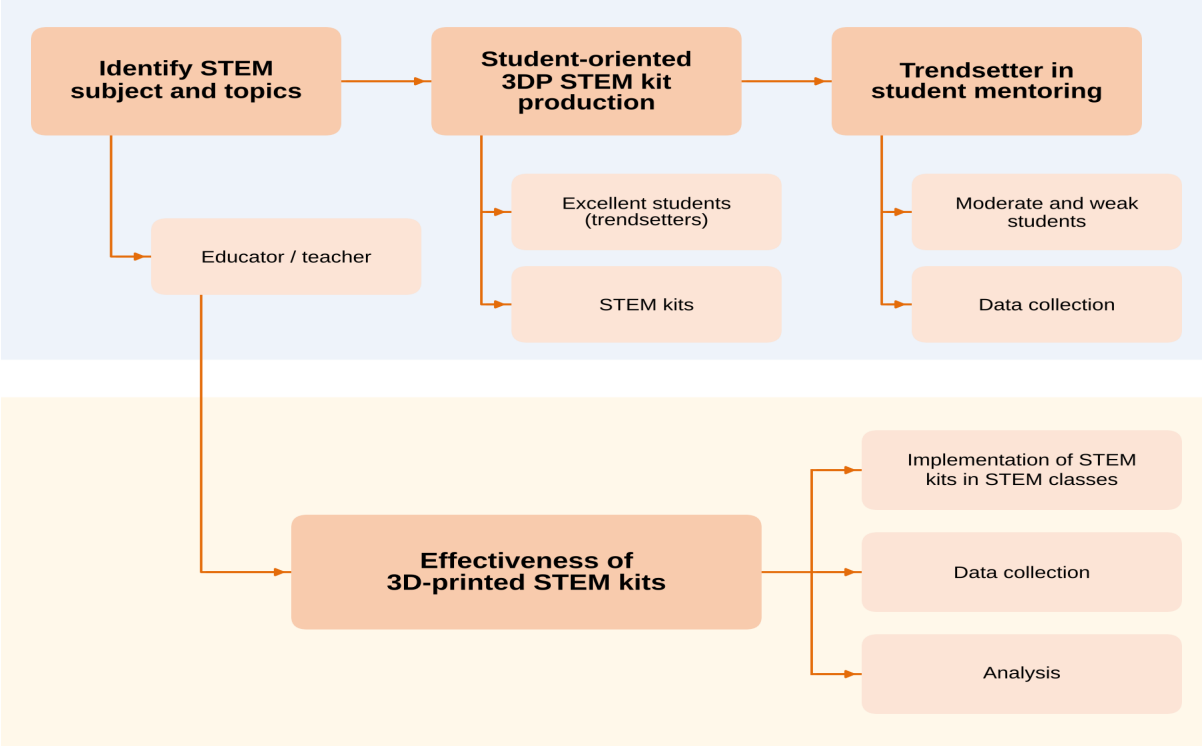
Previously, a student's role as a consumer of information where a conventional approach was applied. In modern learning styles, students have become creators, fostering a sense of ownership and intrinsic motivation (Tabassum et al., 2024). Therefore, when learners are encouraged to design, make, and test their own ideas, they encourage active student participation in the learning process and develop their

collaboration, communication, and creativity skills motivation. This process involved the engagement in higher-order cognitive processes involving analysis, synthesis, and evaluation. Consequently, it strengthens not only academic achievement but also problem-solving skills, resilience, and adaptability (Belcheva, 2024; Bhardwaj et al., 2025).

In addition, seeking and listening to student perspectives can be a worthwhile endeavor since it provides unique insights into life in the classroom as well as the complexities of teaching and learning. Moreover, involving students has the potential to make education more meaningful and appropriate. In addition, as education evolves, many institutions are increasingly adopting more student-centered and active learning methods to better equip students with the challenges and complexities of modern science and technology (Bhardwaj et al., 2025). Hence, the use of students as creators is essential for developing and shaping students' frameworks, which also promotes innovative thinkers, such as education, as science and technology evolve drastically while students are navigating an ever-changing world (Kakarla, 2024).

Figure 1

Relationship Between the Trendsetter Program and 3D Printing (3DP) as a Learning Tool



Note. 3DP = 3D printing; STEM = science, technology, engineering, and mathematics. The upper panel shows the kit development and peer-mentoring pathway; the lower panel shows the evaluation of the kits' effectiveness in STEM classes.

Therefore, in this study, a trendsetter role is created among the students, as the educator perspective might differ from the student's point of view in understanding knowledge. The trendsetters were selected among gifted students, and they were trained with proper communication and teaching skills so that the knowledge medium between the teacher and the student could be minimized. Their knowledge will aid in understanding the complex scope of STEM and the associated student solutions. Consequently, student exposure is leveled and assessed by the students' understanding of project-based learning and hands-on activity. The adaptation of 3D printing (3DP) technology at the secondary school level is an initiative to expedite student interest in learning STEM.

These trendsetters followed a systematic research process in innovating 3D-printed STEM kits through the application of 3D printing technology, accompanied by the development of teaching modules based on the kits produced. The conceptual and theorem on selected topics in STEM can be translated into a teaching kit module that is designed and developed by educators and students. The kits were subsequently implemented with school students, where the trendsetters also conducted a series of interactive activities aimed at enhancing social skills, particularly among gifted learners. This initiative demonstrated the impact of student-oriented 3D printing kit modules in strengthening STEM knowledge, creativity, and engagement in education. The relationships between trendsetters and 3D-printed STEM education are summarized in Figure 1.

LITERATURE REVIEW

Trendsetter Approach in Education

To address declining interest and the abstract nature of secondary STEM education, innovative pedagogical models must move beyond traditional teacher-centered instruction (Foi & Kean, 2022). The Student-as-Trendsetter framework rests at the intersection of social learning theory, which posits that individuals learn behaviors, attitudes, and emotional reactions through peer modeling (Rumjaun & Narod, 2025), and constructionism (Stager, 2025). When students observe relatable peers demonstrating enthusiasm and technical mastery, social barriers to complex subjects diminish. Concurrently, constructionism emphasizes that deep conceptual learning occurs when students actively construct physical artifacts that embody abstract ideas (Stager, 2025). In this context, trendsetters serve as instructional pioneers who design, fabricate, and deliver hands-on STEM learning tools. Rather than acting as passive consumers of textbook material, student-creators take active ownership of knowledge synthesis, fostering intrinsic motivation, critical thinking, and higher-order cognitive processing (Belcheva, 2024; Bhardwaj et al., 2025; Tabassum et al., 2024). By shifting the medium of instruction from teacher-to-student to peer-to-peer, the social and cognitive distance between the instructor and learner is substantially reduced, creating an approachable and engaging learning environment (Parmar et al., 2025).

Therefore, student behavior toward trendsetters and influencers will be the main catalyst in strengthening STEM education. Even if an excellent or gifted student was typically labeled as a bookworm, with appropriate tools and activities, this group might become influential among other students. They are also exceptional, highly motivated and productive individuals (Klimecká, 2023, 2024). Therefore, by selecting gifted students and training them with proper communication and teaching skills, the knowledge medium between teachers and students can be minimized. Trendsetter is the first person or a group who is creating a new teaching method in this context using 3D printing in STEM education. They have been studying STEM since they started secondary school at the age of 13. Therefore, gifted students choose to become trendsetters. Ultimately, the goal is to reduce inequality education, specifically in STEM education, via the 3D Printing Kits Module.

Gift-to-Give Gifted Student Model

Generally, gifted students often possess exceptional motivation, cognitive capacity, and technical potential (Klimecká, 2023, 2024). Hence, students as trendsetters are a gratification to class and their peers, as they are the pioneers in education. In addition, despite the unique achievement of gifted students, especially in terms of their education, the social isolation of this group, as typical science bookworm stereotypes, might lead to depression even at a very young age. In the absence of a proper channel to emphasize their strength toward their same age, their social development will be more bound to close relatives, with a fear of contributing to the community in the future (Worrell et al., 2019). They are likely to turn into volunteers to assist teachers, students, or anyone who needs help.

The trendsetter can be the big league as a peer role model for the students who are endeavour students in the understanding of knowledge. These endeavouring students tend to embrace their quirkiness for being excellent (Noreen et al., 2025). Hence, the trendsetter eventually influences and creates acceptance among other students. Similarly, students are more likely to emulate their peers' behavior, whereby an exceptional persona from a gifted student might represent a translucent interpretation during a learning session.

Role of 3D Printing in Shaping STEM Education

In the past 10 years, 3D printing has been used in the manufacturing field. However, it is costly and unaffordable to own. Recently, 3D printing has become an affordable item that can be owned by people at low cost and is feasible for use as a software that is user friendly and open source (Izharruzzahir et al., 2026; Mohd Rozi et al., 2025; To et al., 2024; Ukoba et al., 2025). Therefore, the use of 3D print in education becomes practicable, as it can be a tool to translate and deliver knowledge from educators to students to improve student understanding (Izharruzzahir et al., 2026; Munir et al., 2025). The educator's perspective might differ from the student's point of view in understanding knowledge; however, with 3D printing kits, students can learn the concept or theorem by developing items that can serve on the basis of their standpoint, especially in STEM education (Faizal Azli et al., 2024; Izharruzzahir et al., 2026). Nevertheless, the educator must be there to ensure that an accurate concept is applied where the preparation becomes crucial in introducing technological and pedagogical changes to impact educational practices (Faizal Azli et al., 2024; Tejera et al., 2025).

Moreover, the technological advancement through Industrial Revolution 4.0 (4IR) has addressed 11 elements, including 3D printing technology as one of the main elements (Gamal et al., 2024; Ukoba et al., 2025). Therefore, to meet the industrialized world, the education field must also be in line with the needs in technology and equip these students for better skill and to improve understanding without using extra cost via the integration of 3D Printing and Industry 4.0 into STEM curricula as an initiative for increasing students' interest in learning STEM in a fun way (Chong et al., 2018; Munir et al., 2025; Tejera et al., 2025). The questions "What will be the effect if students can learn the theorem by touching the theorem?", "How can the student imagination be translated into a real object and learn the concept by project-based learning, hands-on activity and through experience?" can be answered.

Hence, the embrace of 3D printing (3DP) technologies in education is expanding as a tool that is found to take advantage of its functionalities to imitate the wider adoption of technology (Gamal et al., 2024; To et al., 2024). With respect to 3DP, STEM kits at the secondary school level can be developed to adapt to the curriculum for standard-driven instruction and 3D-printable design to create an end-to-end STEM solution (Munir et al., 2025). Hands-on learning is designed to promote deep conceptual understanding, resulting in the great achievement of students in the 21st century (Tejera et al., 2025). In an education system, many additive manufacturing technologies have been developed; however, 3D printing is an economical tool that can be used for the fabrication of advanced prototypes and final products (To et al., 2024).

In recent years, 3D printing has evolved into a feasible technology that everyone can use since the software is user friendly and open source (Tejera et al., 2025). Since 3D-printed educational kits can communicate and convey knowledge from educators to students, their use in education becomes practical, especially for younger learners (Izharruzzahir et al., 2026; To et al., 2024). Hence, incorporating 3D printing technology into STEM subjects can offer an innovative teaching approach that can enhance teaching and learning experience among students (Izharruzzahir et al., 2026; Tejera et al., 2025). This novel approach has the potential to capture students' attention, motivate them to learn, and promote a better understanding of the subject matter.

RESEARCH METHOD

Research Design

In this study, a mixed-method research design was employed, which combined qualitative and quantitative approaches to obtain a comprehensive understanding of students' roles as trendsetters in the development of 3D-printed STEM kits. The qualitative component is structured as a case study that explores students' experiences, decision-making, and creativity throughout the development process. It also measures changes in creativity, confidence, leadership and peer influence on the basis of the student-led innovation project and, consequently, the effectiveness of the developed 3D-printed STEM kits on the basis of the implementation of the kits in the classroom.

Participants

The participants involved in this study consisted of 10 secondary school students from Kolej PERMATA Insan, Negeri Sembilan, Malaysia, which is a gifted school. The selected participants served as trendsetters and were directly involved in the design, fabrication, and testing of 3D-printed STEM kits. They also facilitated peer learning sessions and outreach activities. With respect to trendsetter size, these students ensured high-fidelity mentorship, rigorous technical oversight during CAD and 3D scanning operations, and deep qualitative tracking of student identity evolution. In the implementation phase, in which Gift to Give (gifting students to students) was adopted, 88 secondary school students were involved. This study adopts a purposive sampling approach, focusing on an intensive cohort case study of 10 student innovators.

Research Procedure

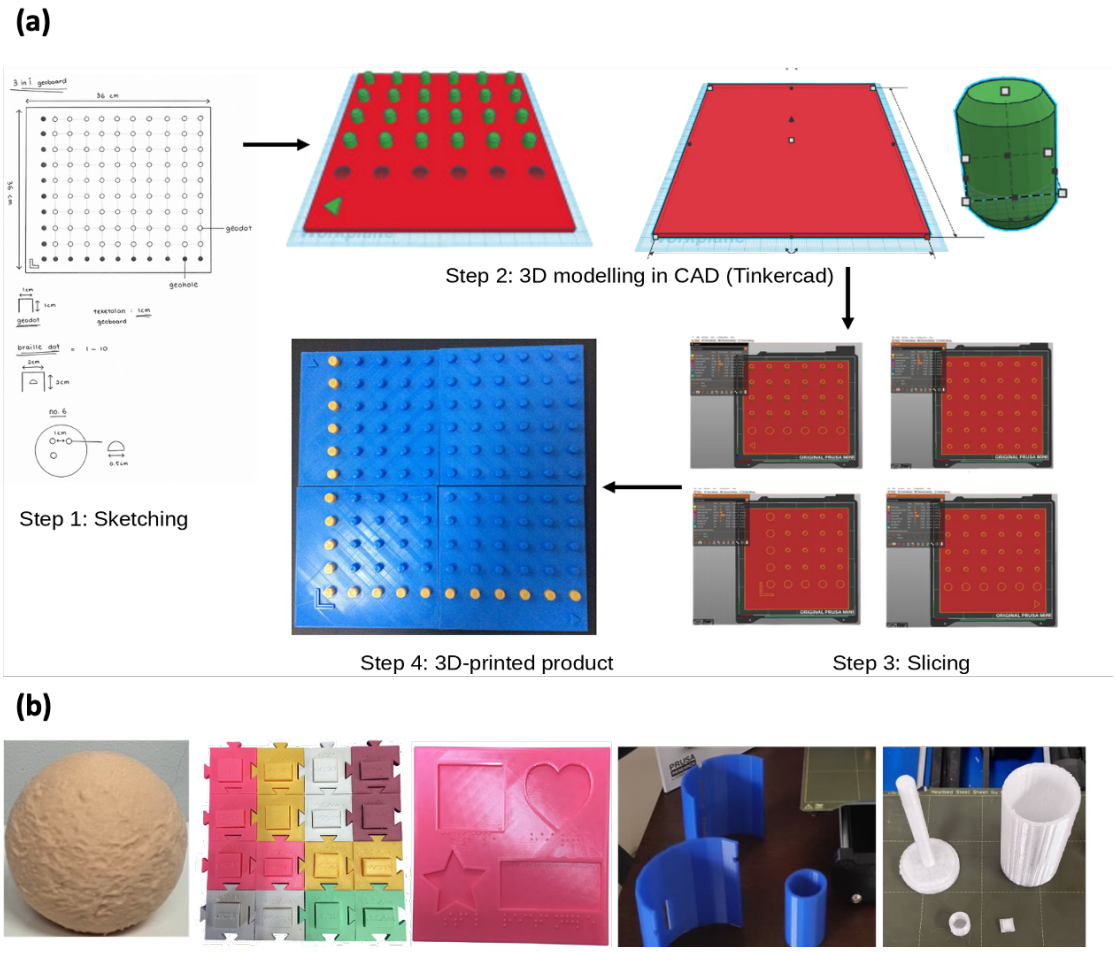
Phase 1: The Co-Design and Prototyping Process

Ideation and Design Thinking. The 3D-printed STEM kits provided trendsetters with a valuable opportunity to apply additive manufacturing technology to develop hand-on learning STEM tools. The process began with design thinking, where trendsetter identified real challenges in the classroom, explored creative solutions through brainstorming and transformed their ideas into prototype designs before the final 3D-printed STEM kits were produced. During this process, they focus on understanding user needs, identifying core problems and using scientific reasoning to refine their designs. This process involves multiple repetitions, as they transform abstract STEM theories into tangible learning tools.

Development process. The trendsetters began by identifying STEM topics that are typically challenging for learners to visualize by surveying the difficulty of STEM topics among school students. The findings from the survey were used to decide which kits to develop. Consequently, the trendsetter used computer-aided design (CAD) software to translate their ideas into digital designs using 3D modeling software. In this study, the students used Tinkercad to design their 3D models. They learned and applied basic to intermediate computer-aided design (CAD) skills, enabling them to produce accurate and functional models. The prototypes were fabricated using 3D printers, allowing students to engage with additive manufacturing processes and material considerations. The development process of the prototype is shown in Figure 2a.

Figure 2

Development of the Parametric 3D-Printed STEM Kits



Note. (a) End-to-end development workflow of a 3D-printed STEM kit (3-in-1 geoboard), from initial sketching and CAD modeling to slicing and final fabrication. (b) Functional parametric 3D models designed in CAD and fabricated by the trendsetters. CAD = computer-aided design.

Phase 2: Technical Fabrication and Material Specifications

In Phase 2, the trendsetter transformed the 3D model prototypes into tangible learning tools using fused deposition modeling (FDM) additive manufacturing technology. The engineering requirements and digital workflows were designed strictly between the two STEM disciplines and the two pathways. With respect to physics and mathematics kits, the workflow relies on generative parametric design. The trendsetter designed the models to meet tight dimensional tolerances and mechanical durability for moving components. In contrast, the complex structures of biological models utilize a reverse engineering workflow aimed at capturing complex and organic anatomical topographies. Hence, the trendsetters used a handheld, structured-light 3D scanner (CR-Scan Ferret) model to digitally capture physical anatomical organ replicas. The resulting raw point cloud data were processed, repaired for mesh manifold integrity and scaled using Tinkercad software to generate high-fidelity digital 3D models before they entered the printing phase.

During the 3D printing process, the trendsetter uses polylactic acid (PLA) filaments as its primary printing material, as PLA has low warpage, strong tensile hold and easily available filaments on the market.

Once the digital designs for both pathways were ready, they were exported as standard .STL files and consequently sliced using Creality Slicer. The manufacturing settings were carefully adjusted for each model, and the moving parts used a sturdy 15% gyroid infill to handle mechanical wear and tear. Moreover, the biological models combined a 15% infill with a fine 0.1 mm layer height to cleanly capture complex structures in detail.

Phase 3: Pedagogical and Professional Evaluation

To evaluate the efficiency of the student-as-trendsetter model within a small sample size, a mixed-methods data collection approach was deployed upon project completion.

Retrospective Quantitative Assessment. As the data were collected postintervention, an online instrument that allowed students to retrospectively contrast their baseline skills against their post-project growth was employed. This approach required the ten ($N = 10$) trendsetters to look back (retrospective pre) and score their original competencies alongside their current abilities (post) right after finishing the project. The instrument utilized a 5-point Likert scale (1 = *novice/no experience*, 5 = *expert/highly proficient*) across four core domains: (1) parametric CAD modeling, (2) 3D scanning and mesh optimization, (3) additive manufacturing (slicing and printing), and (4) pedagogical translation of abstract science.

Qualitative Evaluation. In addition to the quantitative assessment, a qualitative evaluation was developed to evaluate the phenomenological impact of positioning students as trendsetters via open-ended reflective journals through three core themes. The first theme was *technical problem-solving,* in which the trendsetter asked how they handle the constraints during the process, especially in terms of the mechanical tolerance of generative CAD design and the mesh repair of complexities of 3D scanning models. The second theme was *TrendSetter Identity*. The question explored the psychological and academic transformation experienced by the trendsetter during the process from passive consumers to active co-designers who imposed a modern classroom approach. Finally, the third theme was the *professional future,* which evaluated how trendsetter confidence improved after these dual advanced manufacturing workflows were mastered in terms of their tertiary academic pursuits and career trajectories within STEM fields.

Data Analysis Framework

The data did not meet the normality assumptions required for parametric analysis since the sample size was small ($N = 10$). Therefore, the Wilcoxon signed-rank test, which is a robust nonparametric alternative, was used to identify any statistically significant changes in the students' technical confidence (Widiana et al., 2025). With respect to the qualitative data, the textual responses sustain the deductive thematic analysis. The reflective journal entries were systematically analyzed and coded to identify recurring themes related to students' sense of empowerment, their ability to overcome engineering challenges and the development of their professional STEM identity throughout the project.

Moreover, to evaluate the feedback from the 88 classroom participants who experienced the trendsetter-led lessons, the 5-point Likert scale data were analyzed using descriptive statistics. During the analysis, weighted means were used to evaluate the individual items to capture an accurate baseline of participant perceptions across all educational benchmarks. Afterward, the continuous descriptive mean scores were transformed into meaningful and objective qualitative categories. In addition, the feedback was classified by a standard statistical binning approach that divides the score range into equal, mathematically defined intervals. The exact width of each interpretative level was determined by dividing the range of the scale by the total number of desired categories, as expressed in Equation 1.

$$\text{Interval Width} = \frac{\text{Maximum Potential Score} - \text{Minimum Potential Score}}{\text{Number of Target Levels}} = \frac{5-1}{5} = 0.80 \quad (1)$$

Applying a uniform step of 0.80 across the 5-point scale created five mathematically balanced evaluation categories to ensure that the qualitative descriptions assigned to the participant responses were statistically justified rather than arbitrarily defined. The resulting bands are 1.00–1.80 (very low perceived impact; minimal pedagogical efficacy), 1.81–2.60 (low; unsatisfactory efficacy), 2.61–3.40 (moderate; acceptable efficacy), 3.41–4.20 (high; robust efficacy), and 4.21–5.00 (exceptionally high; outstanding efficacy). Therefore, a mean score of 3.41 or above indicates highly successful lesson delivery by the trendsetter. This indirectly shows that the peer-designed 3D-printed STEM kits matched or even surpassed what the target students expected to learn.

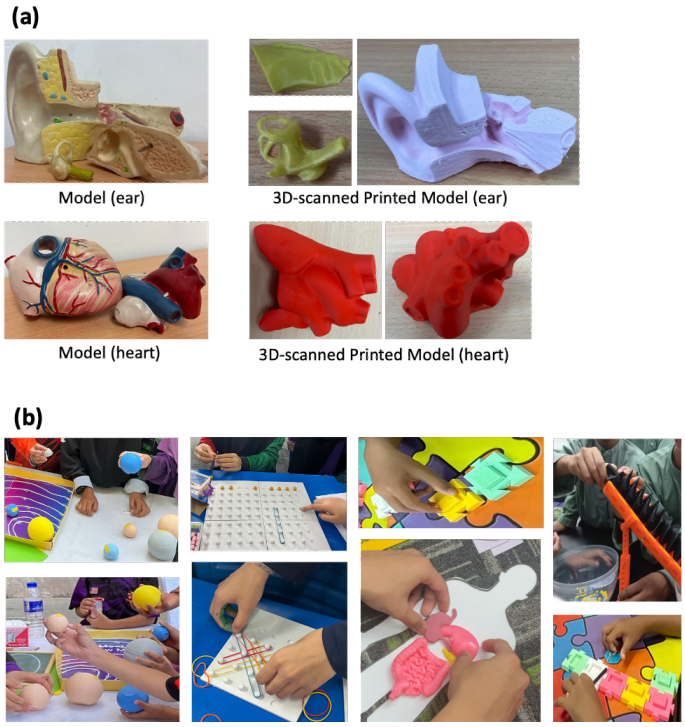
RESULTS

Mechanical Tolerances and Interlocking Functionality

The greatest CAD challenge for the STEM kits was balancing structural strength and precise sizing so that the 3D-printed parts could withstand continuous physical use. The precise dimensions of the 3D-printed components with custom clearance tolerances that kept the moving parts from jamming are shown in Figure 2b. During the process, the trendsetter successfully calibrated the slicing parameters, including infill density and shell thickness, to ensure that the components maintained dimensional integrity during active laboratory experimentation. These results clearly show that when students act as codesigners, they can successfully navigate parametric constraints to build reliable, affordable teaching tools to be used in the classroom.

Figure 3

Reverse-Engineered Biology Models and Classroom Deployment of 3D-Printed STEM Kits



Note. (a) Comparison of physical anatomical organ replicas (left) and the corresponding 3D-scanned printed models (right) for the ear and heart. (b) Field deployment, with classroom participants engaging in tactile exploration of the kits during trendsetter-led sessions.

Surface Fidelity of Reverse-Engineered Organ Models

Unlike the STEM kits, the biology kits using the 3D scanning method prioritized high-fidelity surface detail over mechanical movement. The main challenge experienced by the trendsetter was taking noisy 3D scan data and turning it into clean solid 3D models that were ready for printing. As shown in the side-by-side comparison in Figure 3a, the 3D-printed model captured detailed anatomical features such as the ears and surface textures without the need for expensive commercial production. Hence, by mastering mesh-repair techniques, the trendsetter fixed only small digital glitches such as artifact gaps and nonmanifold edges before printing. As a result, this close visual match shows that student-led reverse engineering is a practical and scalable way to bring high-quality anatomical models into classrooms at a low cost.

Field Deployment and Classroom Pedagogical Utility

The field deployment of the STEM kits was implemented in real classroom settings to observe peer learning and direct engagement, as shown in Figure 3b. The implementation was conducted among 88 participants ($N = 88$) among school students, and a quantitative descriptive analysis was conducted among the participants. The complete response distribution, itemized weighted mean scores, and qualitative interpretations for the eight evaluation items are presented in Table 1.

Table 1

Participants' Evaluation of the Trendsetter-Led Sessions (N = 88)

Item	Response distribution (%)				*M*	*SD*	Perceived impact
	Strongly agree	Agree	Neutral	Disagree			
Q1. The trendsetter stimulated my interest in the activity	46.6	46.6	6.8	0.0	4.40	0.62	Exceptionally high
Q2. The trendsetter managed the activity very well	43.2	46.6	10.2	0.0	4.33	0.66	Exceptionally high
Q3. The trendsetter encouraged discussion and responded to questions	38.6	43.2	15.9	2.3	4.18	0.78	High
Q4. The trendsetter demonstrated in-depth knowledge of the activity	46.6	42.0	11.4	0.0	4.35	0.68	Exceptionally high
Q5. The trendsetter used a variety of instructional methods to attract students' interest	45.5	36.4	18.2	0.0	4.27	0.75	Exceptionally high
Q6. The trendsetter challenged students to do their best work	29.5	54.5	15.9	0.0	4.14	0.66	High
Q7. I like the trendsetter approaches	51.1	36.4	12.5	0.0	4.39	0.70	Exceptionally high
Q8. I hope this kind of teaching approach can be applied in every class	56.8	43.2	0.0	0.0	4.57	0.50	Exceptionally high

Note. Items were rated on a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*); no participant selected *strongly disagree*. The percentages are those of the 88 participants. The perceived impact levels follow the equal-interval bands derived from Equation 1: 1.00–1.80 = very low, 1.81–2.60 = low, 2.61–3.40 = moderate, 3.41–4.20 = high, and 4.21–5.00 = exceptionally high.

The survey results highlight the strong enthusiasm among participants for student-designed STEM kits. As shown in Table 1, all the evaluation items easily obtained the 4.00 mark, and most fell into the *exceptionally high* perceived impact range (4.21–5.00). In particular, Q1 (M = 4.40) and Q7 (M = 4.39) obtained the highest mean scores after Q8, which confirms that the interactive STEM kits effectively drove engagement and student approval.

The response distribution in Table 1 supports these scores, with *strongly agree* and *agree* responses accounting for 81.8% to 100% of the responses on every item. Q6 recorded the lowest mean score (M = 4.14), corresponding to the smallest share of *strongly agree* responses (29.5%), whereas Q3 was the only item to attract any *disagree* responses (2.3%). This slight drop suggests that even in a supportive learning environment, being challenged by a peer instructor introduces a healthy bit of cognitive friction. Interestingly, Q4 (M = 4.35) clearly provides external proof that the technical preparation phase worked. The participants clearly felt that their peer trendsetters knew the material inside and outside, indicating that the demanding CAD modeling and 3D scanning process successfully promoted deep content mastery prior to classroom teaching. These findings confirm that student-led additive manufacturing is a practical and scalable educational approach.

Notably, Q8 ("I hope this kind of teaching approach can be applied in every class") achieved the highest overall score among all survey items (M = 4.57, exceptionally high). This overwhelming endorsement indicates that peer-led, hands-on instructional models are not merely viewed as novelty demonstrations but rather as desirable alternatives to conventional lecture-based methods. The strong positive response to Q8 highlights a clear appetite among secondary school students for scalable, student-centered STEM interventions across the broader curriculum.

Evaluation of Technical Competency

The long-term cognitive and professional growth of the 10 student trendsetters was evaluated using a comparative retrospective pre- and posttest analysis. This matrix measured four essential technical skills, including *parametric CAD modeling*, *3D scanning and mesh optimization*, *additive manufacturing* and *pedagogical translation*. All corresponding statistical metrics using mean shifts, standard deviations, and calculated p values are summarized in Table 2. A statistically significant decrease ($p < .001$) across every skill area was observed. During the retrospective pretest, the trendsetter reported high initial self-efficacy, averaging between 4.30 and 4.90 across domains with tight agreement (SD = 0.30–0.78). However, once they completed the physical fabrication and teaching phases, their self-assessed scores decreased substantially to the *very low* to *moderate* level, with mean scores between 1.80 and 3.00. This is because prior to entering the student-as-trendsetter framework, participants rate their self-assessments on limited software practices, such as drafting basic models or studying 3D printing concepts on paper. However, in reality, idealized digital environments face real manufacturing hurdles, and students overestimate their skills, which explains the high pre-project averages in areas such as parametric CAD modeling (M = 4.60, SD = 0.49). However, turning a perfect digital model into a physical, interlocking assembly immediately brings real-world material limits into play. In addition, qualitative feedback from T07 highlights how hands-on 3D printing forces students to address practical manufacturing hurdles, such as thermal plastic shrinkage, fixed nozzle limits and structural tolerances. Dealing with initial prints that fit poorly forced the trendsetters to recalibrate their idea of what true mastery requires.

This same phenomenon occurred in the 3D scanning and mesh optimization elements. When students faced practical obstacles such as optical scattering on shiny surfaces and complex shapes, their self-assessment scores plummeted from an unrealistic M = 4.90 to a far more realistic M = 3.00. The increased posttest variance (SD = 1.26) illustrates the varied learning curves as students worked through fixing the mesh defects. Ultimately, these results highlight the core strength of the trendsetter model, which cuts through textbook overconfidence by dropping students straight into the realities of applied engineering.

Hence, at the end of the project, their self-assessments were no longer based on guesswork but on a grounded, practical understanding of how modern manufacturing actually works.

Table 2

Trendsetters' Retrospective Pre- and Post-Project Self-Ratings of Technical Competency (N = 10)

Competency domain	Retrospective pre-project		Post-project		*p*
	M (*SD*)	Level	*M* (*SD*)	Level	
Parametric CAD modeling	4.60 (0.49)	Exceptionally high	1.80 (0.75)	Very low	< .001
3D scanning and mesh optimization	4.90 (0.30)	Exceptionally high	3.00 (1.26)	Moderate	< .001
Additive manufacturing (slicing and printing)	4.90 (0.30)	Exceptionally high	2.50 (1.20)	Low	< .001
Pedagogical translation	4.30 (0.78)	Exceptionally high	2.00 (0.89)	Low	< .001

Note. The ratings used a 5-point scale (1 = *novice/no experience*, 5 = *expert/highly proficient*). *p* values are from the Wilcoxon signed-rank test (asymptotic significance). The observed decrease in postintervention self-reported means reflects a cognitive recalibration of technical competence: students shifted from baseline overconfidence (unconscious incompetence in digital environments) to a realistic assessment of engineering constraints (conscious competence in physical fabrication).

Qualitative Analysis of the Thematic Breakdown

Technical Resilience in Dual Workflows

A deductive thematic analysis of reflective journals offered a clear view into the trendsetter experience. This feedback fell into three core thematic pillars that track the trendsetter growth throughout the project. Across these reflections, the trendsetters noted a stark contrast between designing CAD models for the physics and math tools versus reverse-engineering 3D scans for the biological models. For example, Trendsetter T07 wrote the following in their journal:

> One of the greatest technical challenges I faced was ensuring that the CAD-designed Physics kit could be assembled accurately after 3D printing. The first prototypes had fitting issues due to incorrect tolerances, causing some components to be either too tight or too loose. I solved this by modifying the CAD model through several design iterations, testing prototype parts, and measuring components with digital calipers until the dimensions were accurate. (Trendsetter T07)

This reflection clearly highlights the advanced spatial and analytical skills these student trendsetters developed. In typical coursework, students rarely have to troubleshoot mechanical fits on their own since tolerances are usually precalculated by instructors or commercial kit vendors. In contrast, Trendsetter T07 was forced to address real-world tolerance accumulation directly. Students choose to deploy digital calipers and measure physical parts to match dimensional errors back to specific CAD parameters, which demonstrates genuine reverse engineering skills. This active process of testing, measuring and refining designs is precisely why the classroom participants rated the trendsetters' domain expertise so highly in Q4 ($M = 4.35$).

The Evolving Identity of the Student as a Trendsetter

The student as trendsetter framework transformed a fundamental shift in how students viewed their role in the classroom. Shifting from passive recipients to active co-designers cultivated genuine ownership and academic authority, as stated by Trendsetters T02 and T05. As Trendsetter T02 noted, introducing the

physical kit sparked curiosity, with classmates spontaneously asking them to join 3D printing research projects. This social dynamic directly explains the high survey scores for Q1 (M = 4.40, driving interest) and Q7 (M = 4.39, support for the trendsetter model).

> I feel immense pride in achieving something I never imagined I could do. It was amazing to watch my peers become inspired by the 3D printing projects, since it is not very common for students my age, but this project sparked a trend where others actively joined in on the research regarding 3D printing. Seeing them use my physical planet board game to better understand physics while simultaneously learning about the capabilities of 3D printing was deeply rewarding. Having hands-on experience with real-world science and engineering challenges has made me more passionate about pursuing those fields in the future. (Trendsetter T02)

Moreover, Trendsetter T05 noted that connecting abstract engineering with real-world impact directly affects modern design thinking. This shift in mindset explains why the participants during the implementation reacted so positively to the student-led modules, which gave top marks to teaching variety (M = 4.27) and lesson management (M = 4.33). They no longer saw these custom kits as simple toys but as tangible proof of complex theories, especially in learning STEM.

> It helped me to switch from being an active consumer of knowledge from textbooks to being a person who created learning materials for other people. I understood that engineering is not just the creation of theories but the realization of these ideas into real-life objects. (Trendsetter T05)

Long-term Calibration of STEM Career Trajectories

Finally, the framework evaluates its long-term impact on students' career paths and cross-disciplinary skills. While modern industries expect engineers to master both software and physical fabrication, academic programs frequently teach them separately. Therefore, bridging digital modeling with real-world manufacturing helped the trendsetter build genuine confidence across multiple fields. As one trendsetter noted,

> Intensive work with digital design and 3D printing has greatly increased my self-confidence because now I can combine my IT skills with engineering tasks. It has triggered my interest in professional fields that combine computer technologies with engineering. In the future, I will continue to develop my STEM field. (Trendsetter T06)

Furthermore, the trendsetters' commitment to pursuing STEM careers highlights how hands-on additive manufacturing projects drive long-term student retention. These qualitative insights connect cleanly to the survey results in Table 1, specifically the strong scores for Q5 (M = 4.27, instructional variety) and Q7 (M = 4.39, overall approach). Participants who joined the classroom implementation were not merely listening to a conventional student presentation by the trendsetter; however, they were learning from a peer who had actually mastered these interdisciplinary tools firsthand. Ultimately, this proves that moving beyond textbook theory does far more than teaching short-term technical skills. It also permanently reshapes how students see themselves as professionals and strengthens the future STEM workforce.

DISCUSSION AND CONCLUSIONS

Taken together, the quantitative and qualitative strands point to two complementary mechanisms. First, the peer-to-peer channel appeared to reduce the social and cognitive distance between the instructor and learner. This finding is consistent with recent school-level evidence that relatedness conditions, particularly supportive teacher–student relationships and an inclusive classroom climate, are the strongest correlates of active learning engagement (Bhatt, 2026). Second, the decline in the trendsetters' self-ratings mirrors what has been described as an illusion of competence, in which polished outputs produced with supportive digital tools overstate what learners can independently demonstrate (Minh, 2026). Because self-efficacy remains a central focus of research on secondary students' learning performance (Khadka et al.,

2026), the recalibrated, evidence-based confidence observed here may offer a more realistic foundation for future learning than the inflated baseline ratings do. The model also speaks to the challenge of interdisciplinary STEM teaching, in which the integration of unfamiliar disciplinary knowledge presents both advantages and difficulties for educators (Dawkins & Naidu, 2026); here, the student co-designers shared part of that integrative work. These findings should be interpreted with caution given the small purposive sample of 10 trendsetters, the retrospective self-report design, and the absence of a comparison group. Future studies should use larger samples, objective performance measures, and longitudinal follow-up.

In conclusion, this study confirms that the student-as-trendsetter model is a practical and effective approach for secondary school STEM education. Positioning gifted students as co-designers led to the creation of 3D-printed STEM kits and scanned biological replicas that resonated strongly in the classroom trials of 88 students (M = 4.14–4.57). In contrast, tracking the 10 student-creators (trendsetters) revealed a statistically significant decrease in technical self-efficacy ($p < .001$), reflecting a healthy shift from overconfidence to realistic self-assessment. In addition, the transformation from digital design to physical manufacturing exposed these creators to real-world engineering constraints, such as material shrinkage and mechanical tolerances. Hence, navigating these practical hurdles ultimately transformed students into resilient innovators. Overall, this scalable, cost-effective framework offers a proven roadmap for strengthening interdisciplinary STEM engagement and retention.

IMPLICATIONS

In terms of practice, the findings suggest that schools can position gifted or high-achieving students as co-designers and peer facilitators who translate abstract STEM content into tangible, low-cost learning tools, while teachers remain responsible for conceptual accuracy. Desktop 3D printers, free CAD software, and structured reflective journals together offer a replicable model for STEM clubs and enrichment programs. In terms of assessment, the sharp post-project decline in self-ratings indicates that confidence reported only within digital design environments may overstate learners' readiness; teachers should therefore verify skills through physical fabrication tasks before treating confidence as evidence of mastery (Minh, 2026). With respect to policy, the model supports Malaysia's agenda to increase STEM participation (Ministry of Education Malaysia, 2026) by turning student creators into visible role models for their peers.

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