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THE E-MODULE STEM ARGEO PROJECT-BASED LEARNING AS A SUPPORT TOOL FOR LEARNING GEOMETRY CONCEPTS AMONG FORM 2 STUDENTS

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Abstract:

Geometry is a foundational strand of school mathematics, yet many lower secondary students struggle to visualise three-dimensional objects and to connect abstract geometric ideas to real situations. This article reports the analysis phase of a design and development project for the e-Module STEM ARGeo, an electronic learning module that integrates Science, Technology, Engineering and Mathematics (STEM) concepts, Augmented Reality (AR) and Project-Based Learning (PBL) as a support tool for learning geometry concepts among Form 2 students, the year in which the topic is taught. Adopting the Design and Development Research (DDR) approach guided by the ADDIE model, a needs-analysis questionnaire was completed by 414 students across Forms 1 to 3, Form 2 constituting the largest group at 40.09%; the phase was surveyed in full because the difficulties the module addresses develop across it rather than within a single year. Responses were

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recorded on a five-point Likert scale and analysed using percentage, mean and standard deviation. The findings indicate that students report considerable difficulty with geometry, particularly in visualising three-dimensional shapes and in relating geometric ideas to everyday situations; that 69.49% agreed an e-Module is needed to strengthen their understanding of geometry; that 71.25% agreed a module combining STEM and AR should be developed; and that 71.67% agreed project-based learning should be applied. Familiarity with AR was the lowest-rated area, prior use returning the only item mean below the scale midpoint (M = 2.98, SD = 1.11), yet interest in AR was high (M = 3.76, SD = 1.12). These results establish a learner-grounded need for the module and an empirical specification for its design. The study documents perceived needs rather than demonstrated effectiveness; the module's impact on understanding, engagement and achievement remains to be established in the implementation and evaluation phases that follow.

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Introduction

In the present digital era, the use of technology has become pervasive, and learners can access it almost anywhere and at any time (Astalini et al., 2019). Because technology occupies a far larger role today than in previous generations, current learners possess a high degree of technological literacy, and the integration of technology into education can support more efficient and effective learning (Kementerian Pendidikan Malaysia, 2016). For mathematics in particular, the use of technology is no longer optional but a necessity, and digital tools have been shown to raise achievement and engagement among secondary students (Hidayat, Kamarazan, et al., 2023; Hidayat, Noor, et al., 2024). Technological tools allow learners to investigate many strands of mathematics, including geometry, statistics, algebra and number (Fauziah Salleh & Shaharuddin Md Salleh, 2020).

Augmented Reality (AR) is a real-time presentation of a physical object that superimposes virtual content onto the real world in order to enrich an existing object with additional detail (Cahyono et al., 2020). AR therefore offers learners a novel experience in which their immediate surroundings are overlaid with digital learning information, and the number of AR studies in education has expanded markedly over the past decade alongside the proliferation of mobile technology (Hidayat & Wardat, 2023; Nur Izza N. Ahmad & Shahrul Nizam Junaini, 2020). By transforming real objects into virtual images, AR enables students to apply newly acquired knowledge to real artefacts and has been reported to enrich the learning experience and strengthen retention.

Geometry stands out among mathematics topics as particularly suited to this technology, since much of the difficulty learners encounter with it is representational rather than computational. This article reports the analysis phase of a design and development project for the e-Module STEM ARGeo, an electronic module that unites STEM concepts, AR and project-based learning for the teaching of geometry. The sections that follow review the relevant literature, establish the gap the module is intended to fill, and report the needs analysis conducted with lower secondary students to ground its design.

Literature Review

Four bodies of work bear on the development of the e-Module STEM ARGeo: research on augmented reality in mathematics education, research on STEM implementation in Malaysian schools, evidence concerning students' difficulties with geometry, and developmental work on project-based learning and electronic modules. Each is reviewed in turn before the gap they jointly define is set out.

Augmented Reality in Mathematics Education

Mastery of geometric fundamentals and of geometric problem solving enables students to apply mathematics in real situations, and through AR students can build confidence and deepen their understanding by visualising and manipulating three-dimensional objects (Gecu-Parmaksiz & Delialioglu, 2019). Recent experimental work reports that AR can improve academic achievement and motivation in middle-school geometry (Ibáñez et al., 2020), enhance the geometric thinking ability of junior-high students (Pujiastuti & Haryadi, 2024), and raise attainment in secondary geometry classrooms (Beisenbayeva et al., 2024). Comparative studies likewise report gains from AR relative to conventional teaching in school mathematics (Demitriadou et al., 2020). Reviews of the field nevertheless observe that the literature remains fragmented, and that few studies have rigorously synthesised how AR is embedded within a defined pedagogical framework rather than deployed as a standalone visualisation aid (Hidayat & Wardat, 2023; Nur Izza N. Ahmad & Shahrul Nizam Junaini, 2020).

STEM Education and Its Implementation in Malaysia

STEM education is a strategy for promoting teacher and student engagement across two or more domains, frequently through project-based and collaborative learning, and mathematics is regarded as one of the most crucial subjects within STEM programmes (Amalina & Vidákovich, 2022; Hidayat & Wardat, 2023). Malaysia has committed to STEM through successive national policy instruments, yet implementation at school level continues to encounter difficulty. Malaysian studies report that teachers remain underprepared for STEM-based curricular reform, particularly in rural schools (Amirah Abdol Rahman et al., 2018; Nur Amelia Adam & Lilia Halim, 2019), and that shortages of resources, tools and time impede integrated STEM delivery in the classroom (Siti Soraya Ramli et al., 2022). Integrated approaches demand meticulous planning and systematic execution on the part of teachers (Suraya Bahrum et al., 2017), which many cannot sustain without dedicated materials; teachers are consequently found to employ fewer technological elements in their teaching, leaving students disengaged during learning sessions. Among the recommended responses to this shortfall is the development of dedicated STEM education modules, since well-designed modules help learners achieve predetermined learning objectives and can address the shortage of teaching materials.

Difficulties in Learning Geometry

Geometry requires learners to move between two-dimensional representations and three-dimensional objects, to reason about properties that cannot be read directly from a diagram, and to select formulas according to the particular solid concerned. Regional evidence indicates that lower secondary students find these demands considerable: students struggle to compute the surface area and volume of solids because they misapply formulas to particular shapes (Wijayanti et al., 2017), a difficulty traceable to weak visual-spatial reasoning rather than to arithmetic error. Malaysian work reports further that students commonly fail to perceive two-dimensional shapes and three-dimensional solids accurately and are therefore unable to compare their forms and properties reliably (Khaliza Wahid & Norazrena Abu Samah, 2019); the recommended response is that geometry be taught through hands-on activity rather than exposition alone (Mohd Fadzil Abdul Hanid et al., 2022).

National and international assessment evidence points in the same direction, and the trend is unfavourable. Space and shape have been identified as an area of relative weakness for Malaysian students (Kementerian Pendidikan Malaysia, 2016), and Malaysian eighth-grade students recorded an average mathematics score of 411 points in TIMSS 2023, a decline of 50 points from the 461 recorded in TIMSS 2019, with 48% falling below the 400-point Low International Benchmark and only 1% reaching the Advanced Benchmark (von Davier et al., 2024). Geometry is among the mathematics content domains assessed at this level, so the decline bears directly on the topic addressed here. The issue is particularly consequential at Form 2, where geometry occupies a substantial portion of the KSSM mathematics syllabus and where conceptual weaknesses established at this stage carry forward into upper-secondary work.

Project-Based Learning and Electronic Modules

The instructional materials currently available do not adequately address these difficulties. Conventional textbooks and worksheets necessarily present three-dimensional solids as static two-dimensional drawings, which is exactly the representational step that students find hardest; the medium therefore reproduces the obstacle it is meant to overcome. Where digital resources do exist, they are frequently generic applications that are not aligned to the KSSM syllabus and that provide visualisation without an accompanying pedagogical structure. Electronic modules built on project-based learning offer one route beyond this constraint: such modules have been developed and validated for school and post-school settings (Maksum & Purwanto, 2022), and a project-based geometry environment supported by AR has been found to foster positive behavioural intention to use the technology among learners (Malizar & Johar, 2021). Project-based learning is well matched to AR in particular, because it gives learners a concrete artefact to construct and therefore a reason to manipulate the geometric objects the technology makes visible.

Problem Statement

These considerations motivate the development of the e-Module STEM ARGeo, which unites STEM, AR and project-based learning within a single electronic module for the teaching of geometry. Development cannot proceed, however, on the assumption that such a module is either needed or wanted. Within the Design and Development Research tradition, product development is preceded by a systematic needs analysis that establishes whether the intended users experience the problem the product addresses and whether they are receptive to the proposed solution. Proceeding without that step risks producing a technically accomplished module that answers a problem learner do not have, or that adopts a pedagogy they will not engage with. This article reports that needs analysis, and is guided by the question: to what extent do lower secondary students experience difficulty in learning geometry concepts, and to what extent do they perceive a need for an e-Module integrating STEM, AR and project-based learning as a support tool for learning geometry among Form 2 students?

Objectives of the Study

The e-Module STEM ARGeo is designed for Form 2 students, whose syllabus contains the geometry content it addresses and with whom it will be implemented. The needs analysis reported here was conducted across the lower secondary phase, of which Form 2 students formed the largest group; the rationale for this is set out in the methodology. This article reports the analysis phase of the development of the module and is guided by four objectives:

(i) to identify the difficulties students, experience in learning the geometry concepts addressed by the module, and the extent to which they perceive a need for an electronic module to support that learning;
(ii) to determine students' existing knowledge of Augmented Reality and of STEM concepts, and their views on an e-Module integrating STEM and AR as a support tool for learning geometry;
(iii) to determine students' views on project-based learning as the pedagogical approach through which such a module should be delivered; and
(iv) to establish the extent to which the needs analysis justifies the development of the e-Module STEM ARGeo, built on project-based learning, as a support tool for learning geometry concepts among Form 2 students.

Methodology

Research Design

This study employed a quantitative approach within the Design and Development Research (DDR) framework (Richey & Klein, 2007), operationalised through the ADDIE model: Analyse, Design, Develop, Implement and Evaluate (Branch, 2009). DDR is appropriate because the project centres on the systematic development of a specific product, the e-Module STEM ARGeo. The research comprises three phases — analysis, design and development, and evaluation — and the present article reports the analysis phase.

Within ADDIE, the analysis phase is not merely preliminary but constitutive: its function is to generate the specification against which the module is subsequently designed. Each cluster of needs-analysis items was therefore written to inform a particular design decision. Items on difficulty with three-dimensional visualisation were intended to establish whether AR-based manipulation of solids should be a core or a peripheral feature of the module; items on familiarity with AR were intended to establish whether an introductory orientation to the technology must be built into the module before geometry content is introduced; items on knowledge of STEM were intended to establish how explicitly the STEM connections must be scaffolded rather than assumed; and items on project-based learning were intended to establish whether a project structure would be accepted by learners and what form of collaboration it should adopt. The correspondence between the findings obtained and the design decisions they informed is set out explicitly in the section From Needs Analysis to Design Specification below, so that the contribution of this phase to the overall development process can be traced.

Population and Sampling

The target population comprised lower secondary students in national secondary schools (Sekolah Menengah Kebangsaan Harian) in Malaysia. The e-Module STEM ARGeo is designed for Form 2, since the content it addresses — Subtopic 6.1, Geometric Properties of Three-Dimensional Shapes — is located within the Form 2 KSSM mathematics syllabus. The needs analysis was nevertheless conducted across Forms 1 to 3 rather than Form 2 alone, on the reasoning that the difficulties the module is intended to address develop across the lower secondary phase as a whole: Form 1 students approach the topic, Form 2 students encounter it, and Form 3 students carry forward whatever understanding they formed of it. Surveying all three year groups therefore capture the need in prospect, in progress and in retrospect, and yields a design specification less tied to the experience of a single cohort.

The questionnaire was distributed to Malay lower secondary students in the Tanjong Malim district of Perak. Responses were collected over a two-month period through a combination of an online Google Form and printed copies delivered to schools, with follow-up conducted by telephone, instant messaging and social media in order to raise the response rate; 414 responses were obtained. Following the sample-size table of Krejcie and Morgan (1970), a population of ten thousand requires a sample of 384, so the number of responses obtained exceeds the threshold for the targeted population. Because responses were gathered from those students who could be reached rather than from a randomly drawn sampling frame, however, the procedure is more accurately characterised as convenience sampling than as probability sampling (Adams & Lawrence, 2019), a point returned to among the limitations. A separate sample of 30 Form 2 students will participate in the implementation phase of the project; that phase falls outside the scope of the present article and its findings are reported separately.

Respondents

The demographic profile of the 414 respondents is summarised in Table 1. Form 2 students, the intended end-users of the module, formed the largest single group at 40.09% of the sample, with Forms 1 and 3 contributing broadly comparable proportions. The sample was drawn predominantly from urban schools.

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Table 1: Demographic Profile of Needs-Analysis Respondents (N = 414)

Variable	Frequency	Percentage (%)
Form 1	127	30.68
Form 2	166	40.09
Form 3	121	29.23
Male	193	46.62
Female	221	53.38
Urban	363	87.68
Rural	51	12.32

Note. Categories are grouped under Form, Gender and Region. Percentages are of the total sample.
Source: Authors' Own Data

Instruments and Analysis

Six instruments were developed for the project as a whole: the e-Module STEM ARGeo itself, a scoring rubric for project outcomes, and four questionnaires covering needs analysis, validity, usability and interest. Only the needs-analysis questionnaire was administered during the analysis phase reported here. The remaining instruments belong to the design and development and evaluation phases, and their findings are reported separately; they are listed here so that the position of the present article within the wider project is clear.

The needs-analysis questionnaire comprised three parts: Part A on respondent demographics; Part B on students' difficulties with the geometry topic; and Part C on the need to develop an e-Module integrating STEM and AR. Part C was further divided into four sections addressing (1) the need for an e-Module for geometry, (2) students' knowledge of AR, (3) students' knowledge of STEM concepts and their views on a STEM-based module, and (4) students' views on project-based learning. All items in Parts B and C used a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

Data were analysed using descriptive statistics. For each item, the percentage of responses falling in each scale category was computed, together with the mean and standard deviation, so that both the distribution and the central tendency of responses could be examined. Mean scores were interpreted using the conventional three-band classification for five-point scales, in which means from 1.00 to 2.33 indicate a low level of agreement, means from 2.34 to 3.66 a moderate level, and means from 3.67 to 5.00 a high level; these bands divide the scale range into three equal intervals, each of width $(5 - 1) / 3 = 1.33$. Because the analysis is descriptive, the findings characterise the responses of the lower secondary students surveyed and are not tested for statistical significance or generalised beyond that group.

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Results and Discussion

The findings are reported in five sections corresponding to the sections of the questionnaire and are based on the responses of all 414 lower secondary participants. Throughout, the language of the report is deliberately restricted to what the data can support. The questionnaire measured students' perceptions — of their own difficulty, of their familiarity with technology, and of teaching approaches they would welcome. It did not measure geometric competence, technological proficiency or learning outcomes, and the results should be read accordingly.

Students' Reported Difficulties With Geometry

Table 2 presents responses concerning students' self-reported difficulties with geometry. A combined 75.85% of respondents agreed or strongly agreed that they found geometry hard to learn, and 57.01% did not agree that they were able to visualise geometric shapes in three dimensions. This pattern is consistent with earlier findings that students struggle to compute the surface area and volume of solids because they misapply formulas to particular shapes (Wijayanti et al., 2017), although the present data record students' own accounts of that difficulty rather than an independent assessment of it. A majority also reported difficulty in relating geometry to daily life and in understanding abstract geometric principles. More than half agreed that learning with technology could improve their understanding, which indicates receptiveness to a technological intervention rather than evidence that such an intervention would in fact improve understanding (Fauziah Salleh & Shaharuddin Md Salleh, 2020).

Table 2: Responses on Whether Students Experience Difficulty With the Geometry Topic

Statement	1	2	3	4	5	M	SD
1. I find it difficult to learn Geometry.	3.38	15.46	5.31	48.79	27.06	3.81	1.10
2. Geometry is an easy topic for me to grasp.	2.66	11.35	39.37	39.13	7.49	3.37	0.88
3. I have trouble solving geometry problems.	3.14	7.49	32.12	39.86	17.39	3.61	0.96
4. I can visualise the shape of geometry in 3D.	2.66	13.77	40.58	32.85	10.14	3.34	0.93
5. I am able to relate geometry to daily life.	4.83	18.84	41.54	27.54	7.25	3.14	0.96
6. I understand the principles of abstract geometry.	4.35	18.36	42.51	27.29	7.49	3.15	0.95
7. I can calculate the perimeter, area and volume of a 2D shape.	2.17	12.56	36.23	34.06	14.98	3.47	0.97

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8. I can calculate the perimeter, area and volume of a 3D shape.	3.62	14.01	38.89	31.16	12.32	3.35	0.99
9. I understand how to use geometric formulas.	5.07	13.53	39.37	30.92	11.11	3.29	1.00
10. Learning with technology may improve my understanding of geometry.	2.45	11.58	34.06	39.36	12.55	3.48	0.94

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Agree, 5 = Strongly Agree. N = 414. M and SD were computed from the response distribution for each item.
Source: Authors' Own Data

Perceived Need for an e-Module for Geometry

Table 3 reports the perceived need for an electronic module. Most respondents endorsed the value of technology in instruction: 68.36% agreed that integrating technology improves teaching and learning, and 71.98% agreed that it makes teaching more enjoyable. Flipbook-style e-modules were viewed favourably for their accessibility and ease of use. Of particular relevance to the present study, 69.49% agreed that an e-Module should be developed to support their understanding of geometry, and 71.26% agreed that a module setting out how activities are to be carried out would help them follow planned tasks. These responses establish learner demand for the proposed format, complementing the developmental evidence that project-based electronic modules can be produced and validated for school settings (Maksum & Purwanto, 2022).

Table 3: Responses on the Need to Develop an e-Module for the Geometry Topic

Statement	1	2	3	4	5	M	SD
1. Integrating technology as a teaching tool can improve teaching and learning.	2.17	12.56	16.91	40.10	28.26	3.80	1.05
2. Using technology as a teaching tool makes teaching more enjoyable.	3.14	7.49	17.39	39.86	32.12	3.90	1.03
3. Flipbook e-Modules are a good way to use technology in teaching.	1.69	11.86	33.66	37.29	15.50	3.53	0.95
4. A flipbook e-Module can be easily accessed through gadgets.	1.21	10.65	34.38	36.33	17.43	3.58	0.94
5. A flipbook e-Module is easier to use.	2.42	9.68	33.90	37.29	16.71	3.56	0.96
6. e-Modules can improve my understanding of Geometry.	2.42	11.11	35.75	39.13	11.59	3.46	0.92

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7. An e-Module is needed to help my understanding of Geometry.	1.21	13.08	16.22	36.80	32.69	3.87	1.05
8. An e-Module outlining how activities are implemented should be developed.	1.93	10.14	16.67	36.47	34.79	3.92	1.04

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Agree, 5 = Strongly Agree. N = 414. M and SD were computed from the response distribution for each item.
Source: Authors' Own Data

Students' Knowledge of Augmented Reality

Table 4 reveals limited awareness of AR. A combined 65.22% of respondents indicated that they were not familiar with AR, and a majority reported having no experience of an AR application, even though AR features routinely in widely used platforms such as Snapchat, TikTok and Instagram Stories. Students therefore appear to encounter AR without recognising it as such. This finding is consistent with observations that the research literature on AR in mathematics teaching remains fragmented (Nur Izza N. Ahmad & Shahrul Nizam Junaini, 2020). Notably, the highest level of agreement in this section was recorded for the statement expressing interest in learning more about AR, which suggests that unfamiliarity coexists with curiosity. The item means make the pattern plain: prior use of an AR application returned the lowest mean in the entire questionnaire (M = 2.98, SD = 1.11), the only item to fall below the scale midpoint, whereas interest in learning about AR returned one of the highest (M = 3.76, SD = 1.12). For the design of the module, the practical implication is that an orientation to AR cannot be assumed to be unnecessary, but neither is resistance to the technology to be expected (Malizar & Johar, 2021).

Table 4: Responses on Students' Knowledge of Augmented Reality (AR)

Statement	1	2	3	4	5	M	SD
1. I am familiar with Augmented Reality (AR).	8.70	16.91	39.61	23.91	10.87	3.11	1.09
2. I have experienced an Augmented Reality (AR) app.	10.65	21.07	37.77	20.82	9.69	2.98	1.11
3. AR may help students understand Geometry better.	6.78	14.29	40.20	27.60	11.13	3.22	1.04
4. AR might boost my interest in studying Geometry.	6.05	14.53	39.47	28.57	11.38	3.25	1.03
5. I am interested in learning more about Augmented Reality (AR).	2.91	14.33	17.23	34.95	30.58	3.76	1.12

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Agree, 5 = Strongly Agree. N = 414. M and SD were computed from the response distribution for each item.

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Source: Authors' Own Data

Students' Knowledge of STEM and Views on a STEM–AR e-Module

Table 5 indicates that, although many students reported some exposure to STEM, a substantial proportion did not report knowing its definition or understanding its concept, which suggests introduction without sustained engagement. Views on a combined STEM–AR module were nonetheless positive: 73.42% agreed or strongly agreed that such a module could attract their interest in geometry, and 71.25% agreed or strongly agreed that an e-Module combining STEM and AR should be developed to increase their interest in the topic. These figures represent the clearest expression of learner-perceived need for the proposed module. They indicate that students would welcome it; whether it raises interest in practice is a question for the evaluation phase (Amalina & Vidákovich, 2022).

Table 5: Responses on Students' Knowledge of STEM and Views on a STEM e-Module

Statement	1	2	3	4	5	M	SD
1. I know the definition of STEM.	4.36	17.19	39.95	25.42	13.08	3.26	1.03
2. I understand the concept of STEM.	5.09	15.78	41.26	26.22	11.65	3.24	1.02
3. Teachers reveal enough information on STEM education.	4.12	15.74	46.00	24.70	9.44	3.20	0.95
4. This Geometry topic is suitable to be implemented through STEM.	2.66	12.80	27.78	43.96	12.80	3.51	0.96
5. A STEM–AR e-Module could attract my interest in learning Geometry.	2.66	11.84	12.08	40.34	33.08	3.89	1.08
6. A STEM–AR e-Module for Geometry needs to be developed to increase my interest.	2.66	13.29	12.80	41.06	30.19	3.83	1.08

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Agree, 5 = Strongly Agree. N = 414. M and SD were computed from the response distribution for each item.
Source: Authors' Own Data

Students' Views on Project-Based Learning

Table 6 shows strong endorsement of project-based learning. A majority of respondents expressed interest in project-based approaches; 75.55% agreed that PBL could help improve their understanding of geometry and 71.67% agreed that PBL should be applied for this purpose. Furthermore, 71.43% expected PBL to improve their understanding of mathematical concepts more generally, and 63.53% agreed that PBL improves teamwork skills. These responses support the decision to embed a project-based design within the e-Module STEM

ARGeo, in that the pedagogical approach proposed is one that the intended learners say they would welcome (Malizar & Johar, 2021). Every item in this section returned a mean above 3.80, the highest of any section in the questionnaire, with the strongest endorsement recorded for the proposition that project-based learning aids understanding of geometry (M = 4.02, SD = 1.04). These responses do not, however, constitute evidence that project-based learning improves geometric achievement, which has not been tested here.

Table 6: Responses on Students' Views on Project-Based Learning (PBL)

Statement	1	2	3	4	5	M	SD
1. I am interested in project-based learning approaches.	3.14	11.62	20.10	33.42	31.72	3.81	1.12
2. PBL can help me improve my understanding of Geometry.	2.42	7.99	14.04	39.71	35.84	4.02	1.04
3. PBL should be applied to improve my understanding of Geometry.	1.94	10.41	15.98	39.71	31.96	3.89	1.03
4. PBL will help me improve my understanding of mathematical concepts.	0.97	10.65	16.95	35.11	36.32	3.94	1.02
5. Learning is more meaningful when students participate in class activities.	0.73	7.99	23.00	38.74	29.54	3.98	1.00
6. PBL can improve teamwork skills.	0.48	7.25	28.74	30.92	32.61	3.86	0.96

Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Slightly Disagree, 4 = Agree, 5 = Strongly Agree. N = 414. M and SD were computed from the response distribution for each item.
Source: Authors' Own Data

From Needs Analysis to Design Specification

Read together, the five analyses yield a coherent specification for the module rather than a general endorsement of it. Lower secondary students report real difficulty with geometry, concentrated specifically in three-dimensional visualisation and in relating geometric ideas to authentic situations; they are largely unfamiliar with AR while being interested in it; they report shallow engagement with STEM despite some exposure to the term; and they respond positively to project-based work. Each of these findings translates into a concrete design decision, as summarised in Table 7. Documenting this translation is the principal contribution of the analysis phase to the wider development process, since it is the mechanism by which learner needs become product features.

Table 7: Mapping of Needs-Analysis Findings to Design Decisions for the e-Module STEM ARGeo

Needs-analysis finding	Resulting design decision
Students report difficulty visualising solids in three dimensions and applying formulas selectively.	Learners construct each solid themselves in the GeoGebra 3D application before converting it to an augmented-reality view, so that construction precedes visualisation and visualisation precedes computation. Content is scoped to Subtopic 6.1, Geometric Properties of Three-Dimensional Shapes, of the Form 2 KSSM mathematics curriculum.
Students report difficulty relating geometry to daily life.	Three authentic project briefs anchor the module: Geometry City, in which groups design a city of at least five buildings; 3D House, in which groups design a dwelling able to withstand seasonal flooding; and Restaurant Robot, in which groups build a robot and specify its function. Geometric properties are encountered as constraints on a real artefact rather than as isolated facts.
A majority are unfamiliar with AR and report no prior use of an AR application.	A dedicated user manual for the GeoGebra application and AR technology is embedded in the module and accessed by QR code. Following pilot testing, in which some students were unable to follow the written steps, step-by-step video manuals were added alongside the written instructions.
Interest in learning about AR is high despite low familiarity.	AR is positioned as the culminating step of each project, so that the work of constructing a solid resolve in an augmented-reality view of the group's own design, and curiosity carries the initial learning load.
Exposure to STEM is reported but definitional understanding is limited.	Each project carries an explicit STEM integration section and an accompanying STEM teaching-and-learning guide, delivered through the 5E inquiry model — Engage, Explore, Explain, Elaborate and Evaluate — so that the science, technology and engineering dimensions of each geometric task are named rather than assumed.

Project-based learning is strongly endorsed, including as a means of developing teamwork.	Work is organised in groups of three to four students, and each project runs across three sessions of two periods each. The scoring rubric, adapted from the national STEM resource series, assesses group work alongside presentation content, creativity, and the use of GeoGebra and AR.
Students report that a module explaining how activities are to be carried out would help them follow planned tasks.	Each project provides a project implementation flowchart, detailed written instructions, and a suggested daily lesson plan aligned to the Form 2 KSSM curriculum. The scoring rubric is derived directly from those instructions, so that the criteria for full marks are visible to learners from the outset.

Note. Design decisions were enacted during the design and development phase and are reported here to demonstrate the contribution of the analysis phase to the overall development process.
Source: Authors' Own Compilation

The module that resulted from this specification integrates project-based learning as the vehicle for STEM delivery, structured through the 5E inquiry model, with the GeoGebra application and AR technology as the tools through which geometric properties are made visible. Its design is grounded in constructivism, in that learners build understanding through active engagement with their environment, and in constructionism, in that they do so by producing a concrete artefact that is meaningful to them. Content alignment was established against three source documents: the Form 2 KSSM mathematics curriculum and assessment standard document, the Form 2 mathematics textbook, and the national STEM resource series, the last of which also supplied the basis for the scoring rubric.

The completed module was subsequently submitted to a panel of three experts — a STEM excellence teacher who also teaches Form 2 mathematics, a mathematics teacher with experience in electronic module development, and a teacher experienced in the GeoGebra application and AR technology, each with five or more years of relevant experience. Content validity was established by expert consensus using the content validity index, which returned a high level of validity and permitted the module to proceed to implementation. The detailed validation findings fall outside the scope of the present article.

Perceived Need Versus Demonstrated Effectiveness

A distinction that runs through the preceding sections warrants explicit statement. The needs analysis establishes that lower secondary students perceive a need for the e-Module STEM ARGeo and are receptive to its constituent elements. It does not establish that those elements are effective. Students' agreement that AR *may* improve their understanding of geometry is a statement of expectation, not an outcome measure; their positive views of project-based learning indicate willingness to engage with it, not that engagement raises achievement. The experimental literature cited in the introduction provides grounds for expecting benefit (Beisenbayeva et al., 2024; Demitriadou et al., 2020; Ibáñez et al., 2020; Pujiastuti & Haryadi, 2024), but that evidence was generated in other contexts and with other materials, and it cannot be treated as evidence for this module. The proper reading of the present findings is therefore that they justify development and specify its direction, and that the question of impact remains open until the evaluation phase is complete.

Limitations of the Study

Five limitations qualify the findings reported here. First, the study relies entirely on self-reported questionnaire data. Students' accounts of their own difficulty, of their familiarity with AR and of their preference for project-based learning are perceptions, and self-report is subject to acquiescence and social-desirability bias, particularly where items describe an innovation that students may infer their teachers favour. No independent measure of geometric competence or of technological proficiency was obtained.

Second, the sample was bounded both geographically and demographically. Responses were gathered from Malay lower secondary students in a single district, Tanjong Malim in Perak, through channels that reached the students who were accessible rather than a randomly drawn frame, and 87.68% attended urban schools. The findings may therefore not represent the needs of students in other districts or states, of students in rural schools where device access and connectivity may differ materially, or of students from other ethnic groups; the restriction to Malay respondents in particular limits the extent to which the results describe the Malaysian lower secondary population as a whole.

Third, and most importantly, the population surveyed and the population for which the module is intended are not identical. The e-Module STEM ARGeo is designed for Form 2 students, whereas the needs analysis drew on students across Forms 1 to 3, of whom 40.09% were in Form 2. The findings reported here therefore describe the lower secondary phase within which the Form 2 syllabus sits, rather than Form 2 in isolation. This was a deliberate design choice, for the reasons given in the methodology, but it carries a cost: the responses of the three-year groups are reported in aggregate, so the analysis cannot establish whether the needs of Form 2 students differ from those of the phase as a whole. A year-group comparison would settle whether difficulty with three-dimensional visualisation, for instance, eases as students' progress or persists throughout; readers should bear this in mind when relating the findings to the Form 2 module they inform.

Fourth, the analysis is descriptive. Percentages, means and standard deviations characterise the responses obtained but do not test relationships, and no inferential claims are made about differences between subgroups or about the population beyond the sample. Fifth, the data are cross-sectional, capturing students' views at a single point before any exposure to the module; perceptions of AR and of project-based learning may well change once students have used them, and the interest questionnaire administered during the evaluation phase is intended to capture that shift.

Conclusion

This article has reported the analysis phase of a design and development effort to produce the e-Module STEM ARGeo as a support tool for learning geometry concepts among Form 2 students. The needs analysis establishes three things. First, lower secondary students, among whom Form 2 students formed the largest group, report substantial difficulty with geometry, concentrated in the visualisation of three-dimensional shapes, the application of formulas and the connection of geometric ideas to everyday situations. Second, they are largely unaware of

AR, including the AR they already encounter in everyday social media, yet express strong interest in learning about it. Third, they view project-based learning favourably, both as a route to understanding geometry and as a means of developing teamwork.

Taken together, these findings provide a clear, learner-grounded rationale for developing an electronic module that integrates STEM, AR and project-based learning for the Form 2 geometry syllabus, and they specify the form that module should take: AR positioned as a core visualisation tool rather than an embellishment, an explicit orientation to the technology, STEM connections made overt rather than assumed, and a structured project sequence with defined collaborative roles.

It should be emphasised that these findings establish need and receptiveness, not effectiveness. The data document what lower secondary students report finding difficult and what they say they would welcome. They do not demonstrate that AR improves geometric understanding, that a STEM framing raises interest, or that project-based learning increases achievement. Such claims can be substantiated only through the implementation and evaluation phases that follow. The appropriate conclusion is therefore that the development of the e-Module STEM ARGeo is well justified by the documented needs of its intended users, and that its impact on students' learning, engagement and achievement remains to be determined.

Recommendations and Future Research

The immediate priority is the completion of the remaining DDR phases. These comprise: (i) the design and development of the module in accordance with the specification set out in Table 7; (ii) expert validation, in which content specialists in mathematics education and specialists in instructional design evaluate the module against the validity questionnaire; (iii) usability testing with a small group of Form 2 students to identify difficulties in navigation, AR marker recognition and task comprehension before full implementation; (iv) implementation with the Form 2 sample identified for that phase; and (v) empirical evaluation of effectiveness, employing a pre-test and post-test design with a comparison group taught through conventional methods, together with the interest questionnaire and the scoring rubric for project outcomes.
A secondary analysis of the existing dataset is also warranted. Because responses were collected from Forms 1, 2 and 3, the data permit a comparison across year groups that the present aggregate analysis does not exploit; establishing whether geometric difficulty and receptiveness to technology vary by year of study would refine the sequencing of the module and indicate whether it might be extended beyond Form 2. Beyond the immediate project, three further lines of inquiry are recommended. Research from the teacher's perspective is needed, since the practicability of any module depends on the preparation, confidence and device access of the teachers expected to deliver it, and this study surveyed only students. Replication across a wider geographic range, including rural schools and other states, would establish whether the needs documented here are general or particular to a predominantly urban district in Perak. Finally, longitudinal work following students beyond a single intervention would help determine whether any gains in geometric understanding or interest are sustained, which short-term evaluation designs cannot establish.

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