Journal of Education and Learning (EduLearn)
Vol. 20, No. 3, August 2026, pp. 1659~1671
ISSN: 2089-9823, DOI: 10.11591/edulearn.v20i3.24313

Developing and assessing the usability of a Visual Geometry Kit for orthogonal projection, plan and elevation

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Article Info

Article history:

Received Dec 29, 2024
Revised Jul 28, 2025
Accepted Sep 30, 2025

Keywords:

Kit
Mathematics education
Orthogonal projection
Plans and elevations
Spatial visualization ability

ABSTRACT

This study aims to develop and evaluate the validity and usability of the Visual Geometry Kit (VGK) for the Form 3 topic of plans and elevations. Using the analysis, design, development, implementation, and evaluation (ADDIE) instructional model, this developmental research design (DRD) involved 3 experts for validation and 50 Form 3 students from a Kuala Lumpur school for usability testing. Data were analyzed using the content validity index (CVI) and descriptive statistics. Results show a CVI value of 1.00, indicating high validity and usability across constructs like usefulness, ease of use, ease of learning, and user satisfaction. The kit effectively supports students in understanding orthogonal projection, plans, and elevations of 2D and 3D shapes. It offers a practical teaching and learning alternative in mathematics, enhancing students' visualization skills and benefiting teachers in explaining these concepts.

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1. INTRODUCTION

Geometry, a fundamental branch in mathematics, immerses learners in the captivating world of shapes and diagrams and equips them with the tools to decipher their inherent characteristics. It represents a journey of cognitive development, commencing with the tangible and gradually ascending to the abstract, transitioning from the intuitive to the analytical, and evolving from exploration to mastery, as reviewed by Lin [1] and Zulkiflee *et al.* [2]. In the intricate world of geometry, the ability to grasp and understand how objects occupy synthesizing utmost importance. The skill to visualize shapes and structures may contribute to the ability in understanding and working with geometric figures. Among the many mathematical knowledge that relies on this critical skill, one that shines is the fascinating concept known as plans and elevations [3], [4]. Plans and elevations constitute a crucial facet of geometry, encompassing 2 core content areas: orthogonal projection as well as plans and elevations. These concepts hold particular significance in the Malaysian educational landscape, where they are systematically introduced to students at the tender age of 15, typically at the Form 3 level. This inclusion is to deliberate pedagogical choice and align with the Kurikulum Standard Sekolah Menengah (KSSM) or Standards-Based Curriculum for Secondary Schools.

Spatial visualization ability can also be defined as spatial awareness, which enables an individual to imagine and translate an object into a simpler form [5], [6]. This ability is crucial in geometry because Plans and elevations require students to be imaginative and it equips students to generate two-dimensional

representations of three-dimensional structures [7]–[9]. According to previous studies [10]–[12], students' visualization abilities still need to improve. Furthermore, this is supported by studies in [13], [14] study which stated that students' visual skills are low, thus emphasizing the importance of visualization skills in geometry learning. However, a key problem remains: how can we effectively address the difficulties students face in developing strong spatial visualization skills specifically for understanding orthogonal projection, plan, and elevation? This study proposes the development of a Visual Geometry Kit (VGK) which contributes to the strengthening of the concept of the plans and elevations topic, especially in drawing orthogonal projections, comparing and contrasting objects and corresponding orthogonal projections, drawing plans and elevations of an object to scale, and synthesizing plans and elevations of an object and sketching the object itself.

Moreover, in solving geometry problems, students require creative thinking patterns in applying concepts and skills to solve these problems. Therefore, using teaching aids is highly suitable to encourage student's inquiry and discovery [15]. Using learning aids in teaching can help stimulate students' interest in learning and make learning more efficient [16]–[18]. According to Hui *et al.* [19], learning geometry promotes inquiry-based learning. It can enhance students' cognitive and psychomotor abilities, indicating that using concrete materials involving geometric concepts can stimulate multiple senses because of the tactile and manipulative nature of the materials [20], [21].

While prior efforts have explored the use of tools like the orthogonal projector kit (OPK) [22] and SketchUp Make [23] for teaching plans and elevations, these approaches present certain limitations. The OPK does not fully encompass the entire learning standards for the topic, while SketchUp Make, being software-based, lacks the tangible interaction crucial for developing spatial reasoning through touch. In contrast, this study introduces a novel VGK PD.T3 (Plan & Elevation Form 3) specifically designed to address the complete spectrum of Form 3 learning standards for plans and elevations. The key novelty of this kit lies in its integration of tangible, touch-based materials that encourage inquiry and discovery, directly supporting the development of students' spatial visualization abilities. By providing a hands-on approach that allows for physical exploration, this VGK aims to offer a unique and more comprehensive learning experience compared to existing tools, ultimately contributing to a stronger conceptual understanding of orthogonal projection, comparison of objects and their projections, scaled drawing of plans and elevations, and the synthesis of these views to visualize the original object.

Although spatial visualization plays a crucial role in learning geometry, many students still find it difficult to grasp concepts like orthogonal projection, plans, and elevations. These topics are often too abstract, making them hard to understand through traditional teaching methods that mainly use flat images or digital tools. For some learners, especially those who benefit from hands-on activities, this approach simply is not enough. Existing teaching aids, whether physical kits or software, tend to fall short. They either do not fully match the curriculum or lack the interactive, tactile element needed to help students truly engage with the material. Because of this, there's a clear need for a teaching tool that not only meets curriculum standards but also encourages active, physical learning. This study responds to that need by introducing a VGK designed to help students explore and understand these geometric ideas in a more meaningful and interactive way.

2. METHOD

2.1. Research design

In this study, the research methodology is grounded in the design framework known as the developmental research design (DRD), as presented in [24]. Within this framework, the instructional model employed is the ADDIE model, which consists of 5 distinct phases. Notably, the ADDIE model has demonstrated its effectiveness in crafting engaging teaching kits that capture students' interest [25].

As explained in [26], the 5 distinct phases of the ADDIE instructional design model: analysis, design, development, implementation, and evaluation. Consequently, the researcher opted for the ADDIE model to guide the development of the teaching kit, primarily because of its comprehensive and exhaustive nature. The model's inclusion of well-defined phases and processes makes it particularly well-suited for the intricate task of kit development. It ensures that every aspect of the creation process is methodically addressed, from the initial analysis of needs to the final evaluation of the kit's usability, thus enhancing its suitability for this research endeavor.

2.2. Population and sample

In research, the population encompasses the entire group of individuals sharing specific characteristics relevant to the study, while the sample represents a subset of this population selected through particular methods [27]. For this initial phase of the study, the target population consisted of 130 Form 3

students from a single secondary school located in the Keramat District, Kuala Lumpur. The selection of this school was purposeful, based on their established use of teaching aids for the plans and elevations topic, providing a relevant context for evaluating the proposed VGK.

The sample for this initial usability study comprised 50 students, selected using a convenience sampling technique. The primary inclusion criterion was being a Form 3 student actively enrolled in the selected school and currently learning the topic of plans and elevations. The main exclusion criterion was any student not part of the Form 3 cohort or not yet exposed to the plans and elevations curriculum. This sample size was determined to be sufficient for an initial assessment of the usability and feasibility of the VGK within a real classroom setting [28], [29]. Given the exploratory nature of this phase, the focus was on gathering rich, qualitative feedback and identifying potential areas for refinement in the kit's design and implementation. Logistical constraints, including limited access to multiple schools within the timeframe of this study and the intensive nature of the usability testing procedures, made a larger sample size of 100 impractical at this stage. Future research will certainly aim to broaden the scope by including a larger and more diverse sample, potentially involving multiple schools and employing more probabilistic sampling methods, to further validate the effectiveness and wider applicability of the VGK. However, the insights gained from this initial study with 50 participants provide a crucial foundation for these subsequent investigations and offer valuable, context-specific feedback on the kit's design and implementation.

2.3. Research instruments and data analysis

In this study, we employed 2 assessment tools: the kit validity form (KVF) and the usability assessment form (UAF). These tools were chosen due to their alignment with the content areas covered during kit development, namely; i) orthogonal projection and ii) plans and elevations. Both instruments used a four-point Likert scale, a widely used research scale designed for gauging opinions. This Likert scale consisted of 4 distinct levels of agreement: (1) strongly disagree; (2) disagree; (3) agree; and (4) strongly agree. The KVF was structured into 2 main sections: assessing the kit's face validity and evaluating its content validity, which encompassed 16 items. For content validity assessment, a panel of 3 experts, including 2 seasoned Mathematics teachers with over a decade of experience and a Mathematics lecturer from a public university, conducted the evaluation.

On the other hand, the UAF focused on 4 primary constructs: i) usefulness; ii) ease of use; iii) ease of learning; and iv) satisfaction. To assess kit usability using the UAF, a questionnaire was administered to a convenience sample of 50 students from a school in Keramat District of Kuala Lumpur. To determine the content validity of the KVF, we calculated the content validity index (CVI) based on the data collected using the Likert scale. A CVI value of ≥0.78, as recommended by Yusoff [30], is considered satisfactory and indicative of a high level of validity for developing the VGK. The kit's validity is deemed adequate if the CVI value surpasses this threshold. For the UAF, the assessment of kit usability will involve descriptive analysis utilizing minimum score values derived from the four-point Likert scale, as adapted from Koo and Yang [31], Table 1. This Table 1 serves as a reference point for determining the level of kit usability based on the minimum score achieved.

Table 1. Interpretation of mean score for analysis of UAF for each construct

Mean score	Mean interpretation
1.00-1.75	Not relevant
1.76-2.50	Low
2.51-3.25	Intermediate
3.26-4.00	High

3. RESULTS AND DISCUSSION

3.1. Development of the visual geometry

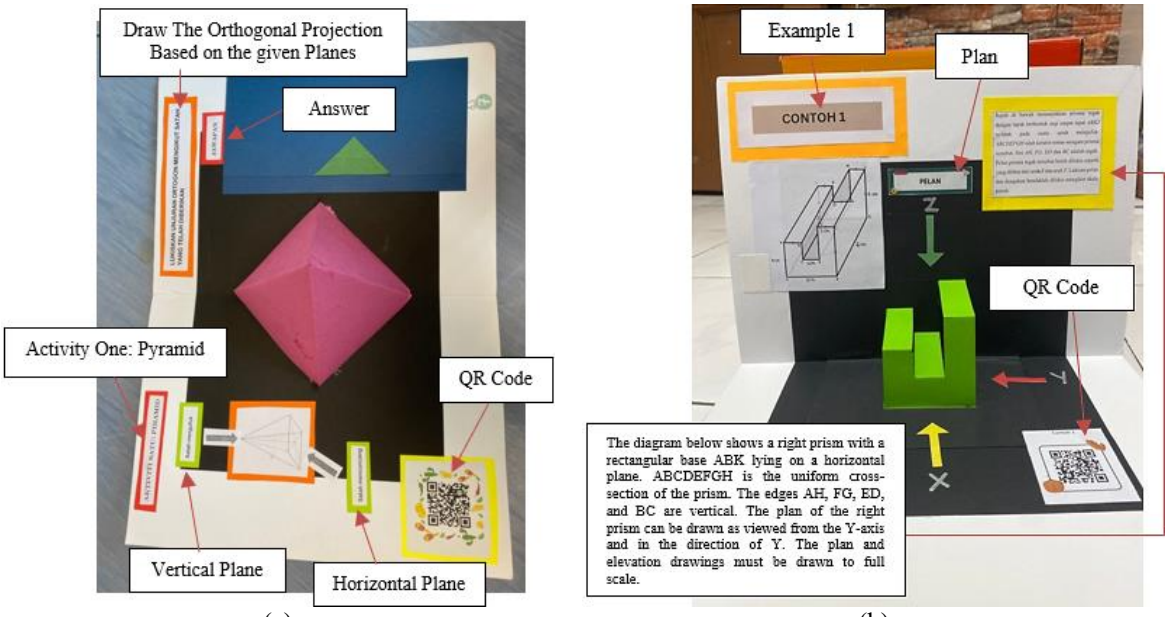
The development of the VGK, guided by the ADDIE model, comprised 5 key phases: analysis, design, development, implementation, and evaluation. The initial phase, analysis, involved gathering information through observation and extensive literature review to evaluate the suitability of the kit's features and structure. Moving to the second phase, design entailed creating a preliminary layout or blueprint for the kit and identifying crucial components to be incorporated into its construction.

The principles of constructivism theory underpinned this endeavor, emphasizing active student engagement and cultivating higher-order thinking skills that were previously challenging to attain. In line with this theory, active learning entails students in constructing their understanding from information and experiences. Thus, this kit's design was imbued with constructivism theory elements to promote active learning. Students can expand their visualization skills through this kit while delving into new knowledge.

The third phase, development, encompassed the creation of the VGK and the preparation of the research instruments (KVF and UAF), both of which were adapted from Arbin *et al.* [32]. The VGK comprised 2 sections aligned with the topics of orthogonal projection and plans and elevations, as shown in Figure 1, Figure 2, Figure 3, and Figure 4. Each section consisted of five essential components, including the cover, comprehensive examples with solutions, QR codes for concise notes, digital 3D models, and a manual for utilizing GeoGebra software. Detailed component lists for both content areas are presented in Figure 1(a) and Figure 1(b) for digital 3D models by GeoGebra, Figure 2(a) and Figure 2(b) for examples of complete answers and QR codes for concise notes, Figure 3(a) and Figure 3(b) for digital 3D models by GeoGebra, and Figure 4(a) and Figure 4(b) for concise notes, exercise questions, answers, digital 3D models, and the GeoGebra software user manual using the Padlet platform.

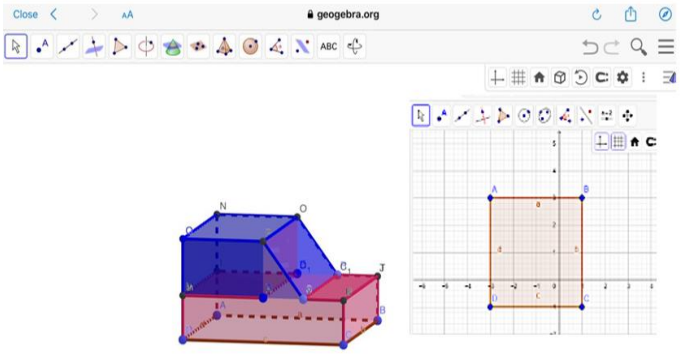
(a) (b)

Figure 1. Front cover of the VGK for (a) orthogonal projection and (b) plans and elevations

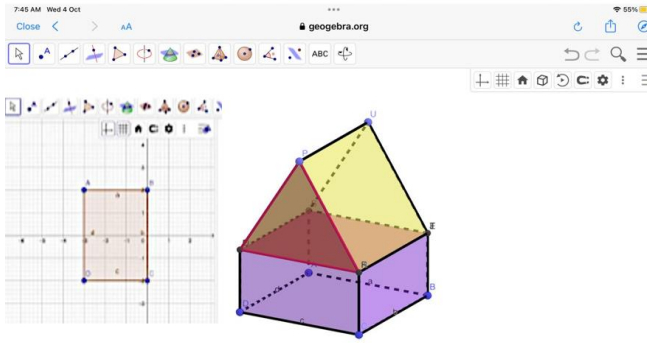


(a) (b)

Figure 2. Examples of complete answers in QR code for concise notes for (a) orthogonal projection and (b) plans and elevations

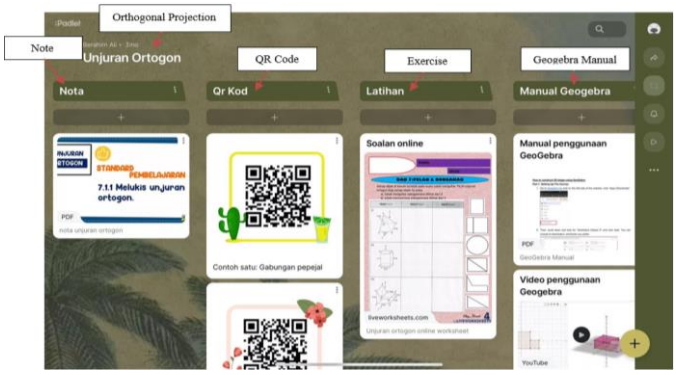


(a)

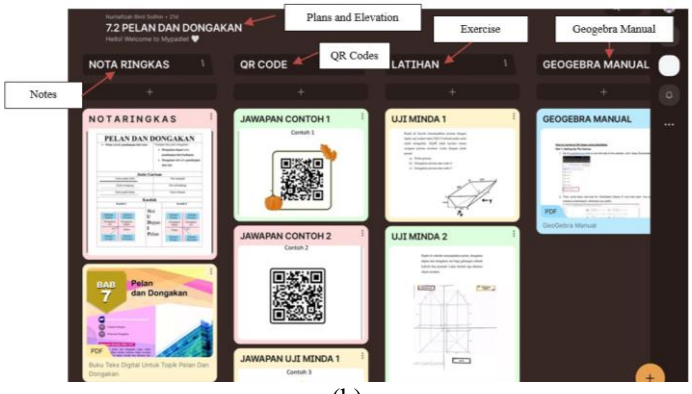


(b)

Figure 3. Digital 3D models by GeoGebra for (a) orthogonal projection and (b) plans and elevations



(a)



(b)

Figure 4. Concise notes, exercise questions, answers, digital 3D models, and GeoGebra software user manual using the Padlet platform for (a) orthogonal projection and (b) plans and elevations

3.2. Face validity

Table 2 provides an overview of the research outcomes pertaining to the face validity assessment of the VGK in relation to both covered topics. The data within the tables revealed that the CVI scored a perfect 1.00 for all 8 items, as consistently affirmed by feedback from all 3 experts involved in the evaluation process. This unanimous consensus among the experts signified a high degree of agreement regarding the face validity of the kit. The research findings unequivocally established that the CVI for the VGK stood at a commendable 1.00, indicating an exceptionally strong level of face validity. In light of this comprehensive analysis and the unanimous agreement among experts, the kit's design, size, and materials have been meticulously crafted. The kits are indeed well-suited for the utilization of students within educational settings.

Table 2. Face validity results of the VGK

Criteria	Expert 1	Expert 2	Expert 3	CVI Value
The language used in this kit is easy to understand.	1	1	1	1
The grammar used in the kit is appropriate.	1	1	1	1
The instructions in the kit are clear and organized.	1	1	1	1
The spelling in the kit is correct.	1	1	1	1
The terms used in the kit are appropriate.	1	1	1	1
The font type in this kit is appropriate	1	1	1	1
The digital text and graphics presentation in this kit are appropriate and engaging.	1	1	1	1
The information presented in the kit is clear and engaging.	1	1	1	1
CVI-relevancy	1	1	1	
			S-CVI value	1

3.3. Content validity of the VGK

Table 3 provides an in-depth insight into the outcomes derived from the content validity evaluation of the developed VGK. The research findings revealed that the CVI for the content validity assessment of the kit attained a perfect score of 1.00, underscoring a notably high level of satisfaction and adequacy in this regard. In accordance with the guidance articulated, which stipulated that a CVI value of 0.80 or higher is considered both suitable and acceptable for expert assessments involving a panel of 3 or more experts, the VGK that has been meticulously crafted was indeed well-suited for educational use [33]. This implies that the kit is aptly designed to facilitate the teaching and comprehension of the intricate concepts encapsulated within both the orthogonal projection, plans and elevations topics.

Table 3. Content validity results of the VGK

Criteria	Expert 1	Expert 2	Expert 3	CVI Value
The kit content aligns with the Malaysian Standard Curriculum of Mathematics for Form 3.	1	1	1	1
The kit content is directly related to the learning standards.	1	1	1	1
The kit content is suitable for the level of ability of Form 3 students.	1	1	1	1
The kit content is consistent with the experience of Form 3 students.	1	1	1	1
The kit content is aligned with exploration-based activities.	1	1	1	1
The kit content can enhance students' understanding of the orthogonal projection content standard of Form 3.	1	1	1	1
The kit content can enhance students' understanding of the plan and elevation content standard of Form 3.	1	1	1	1
The kit content can improve students' visualization skills related to the orthogonal projection content standard of Form 3.	1	1	1	1
The kit content can improve students' visualization skills related to the plan and elevation content standard of Form 3.	1	1	1	1
The kit content is suitable for encouraging inquiry-based discovery.	1	1	1	1
CVI-relevancy	1	1	1	
			S-CVI value	1

3.4. Usability of the VGK

The assessment of the VGK's usability encompassed 4 distinct constructs: usefulness, ease of use, ease of learning, and satisfaction. Table 4 presented, focuses on the results derived from the usability analysis of the "usefulness" construct for both content areas. The analysis outcomes pertaining to the "usefulness" aspect revealed a predominantly positive response from the survey respondents. Most respondents expressed favorable opinions across all items on the agree and strongly agree scales. This suggests that the kit effectively caters to the needs of students, as evidenced by more than 33 students strongly agreeing that it proved useful in comprehending both orthogonal projection, plan and elevation concepts.

Furthermore, it is noteworthy that the VGK was perceived as a valuable time-saving tool in the learning process. This is highlighted by the mean scores, as depicted in Table 4, with item 2 scoring 3.76 and item 8 scoring 3.68. These mean scores, exceeding 3.60, signified that the kit is highly effective in aiding comprehension, expediting the learning process, fostering enthusiasm for learning, and ultimately aligning with the educational requirements of students.

Table 5 provides a comprehensive overview of the usability assessment result for the "ease of use" construct of the VGK. Among the various aspects assessed, the highest score within this construct was observed in item 2, which indicates that the VGK is remarkably user-friendly, attaining an impressive mean score of 3.76. This underscores the kit's capacity to be easily navigated and operated by users. Furthermore, a mean score of 3.74 in item 3 suggested that the kit exhibits flexibility and effectiveness in facilitating the learning of orthogonal projection. Notably, 36 students strongly agreed that the kit is user-friendly in comprehending both orthogonal projection, plan and elevation concepts. Additionally, the findings revealed that students can effectively utilize the kit without written instructions, as demonstrated by the mean scores of 3.70 for both item 4 and item 6. Most items within this construct also garnered mean scores surpassing 3.60, indicating a consensus that the VGK is indeed user-friendly and easy to navigate.

Table 4. Usability results of the VGK for the usefulness construct

Item	Criteria	Assessment scale				Mean
		Strongly disagree	Disagree	Agree	Strongly agree	
1.	The VGK provides an experience that helps me in learning orthogonal projection.	-	-	13 (26.0%)	37 (74.0%)	3.74
2.	The VGK is very useful to me in understanding the concept of orthogonal projection.	-	-	15 (30.0%)	35 (70.0%)	3.70
3.	The VGK saves my time in learning the orthogonal projection.	-	-	12 (24.0%)	38 (76.0%)	3.76
4.	The VGK enhances my understanding of orthogonal projection.	-	-	6 (12.0%)	44 (88.0%)	3.88
5.	The VGK helps me to become more excited in learning the orthogonal projection.	-	-	8 (16.0%)	42 (84.0%)	3.84
6.	The VGK meets my needs in studying orthogonal projection.	-	-	7 (14.0%)	43 (86.0%)	3.86
7.	The VGK provides an experience that helps me in learning plans and elevations.	-	-	14 (28.0%)	36 (72.0%)	3.72
8.	The VGK is very useful to me in understanding the concepts of plans and elevations.	-	-	17 (34.0%)	33 (66.0%)	3.66
9.	The VGK saves my time in learning the plans and elevations.	-	-	16 (32.0%)	34 (68.0%)	3.68
10.	The VGK enhances my understanding of plans and elevations.	-	-	12 (24.0%)	38 (76.0%)	3.76
11.	The VGK helps me to become more excited in learning the plans and elevations.	-	-	12 (24.0%)	38 (76.0%)	3.74
12.	The VGK meets my needs in studying plans and elevations.	-	-	19 (38.0%)	31 (62.0%)	3.62
	Overall mean	-	-			3.74

Table 5. Usability results of the VGK for the ease to use construct

Item	Criteria	Assessment scale				Mean
		Strongly disagree	Disagree	Agree	Strongly agree	
1.	The kit is easy to use.	-	-	14 (28.0%)	36 (72.0%)	3.72
2.	The kit is user-friendly.	-	-	12 (24.0%)	38 (76.0%)	3.76
3.	The kit is flexible.	-	-	13 (26.0%)	37 (74.0%)	3.74
4.	The kit can be used without written instructions.	-	-	15 (30.0%)	35 (70.0%)	3.70
5.	I can complete tasks easily using the kit.	-	-	19 (38.0%)	31 (62.0%)	3.62
6.	I can successfully use the kit for each learning activity.	-	-	15 (30.0%)	35 (70.0%)	3.70
7.	I can successfully use this kit to learn orthogonal projection.	-	-	13 (26.0%)	37 (74.0%)	3.74
8.	I can successfully use this kit to learn plans and elevations.	-	-	16 (32.0%)	34 (68.0%)	3.68
	Overall mean	-	-			3.71

Table 6 provides a comprehensive overview of the usability analysis result for the "ease of learning" construct of the VGK. This assessment revealed that the kit is highly conducive to the learning process of orthogonal projection, plans and elevations, as indicated by their impressive mean scores of 3.74 and 3.90, as denoted in item 1 and item 2. Furthermore, the findings demonstrated that a significant number of students, precisely 38, strongly agreed that the procedure involving technology, digital notes, and digital and printed exercises is user-friendly and adequately aids in comprehending these complex concepts.

Moreover, over 40 students strongly agreed that the kit facilitates rapid learning of these 2 topics, underscoring its efficacy in expediting the learning process. Items 10, 11, and 12, each achieving mean scores of 3.63, 3.70, and 3.66, further validated the ease of learning facilitated by the VGK. These scores indicated that the answers provided for printed and digital exercises and instructions for exploratory activities are straightforward to use as reference materials and are presented clearly.

Table 6. Usability results of the VGK for the Ease of Learning Construct

Item	Criteria	Assessment scale				Mean
		Strongly disagree	Disagree	Agree	Strongly agree	
1.	I can easily learn the content standards of orthogonal projection using the kit.	-	-	13 (26.0%)	37 (74.0 %)	3.74
2.	I can easily learn the content standards of plan and Elevations using the kit.	-	-	5 (10.0%)	45 (90.0%)	3.90
3.	I can quickly learn the content standards of orthogonal projection using the kit.	-	-	10 (20.0%)	40 (80.0%)	3.80
4.	I can quickly learn the content standards of plan and elevations using the kit.	-	-	3 (6.0%)	47 (94.0%)	3.94
5.	The procedure for using the technology in the kit is easy to understand.	-	-	12 (24.0%)	38 (76.0%)	3.76
6.	The printed summary notes in the kit are easy to understand.	-	-	14 (28.0%)	36 (72.0%)	3.72
7.	The digital summary notes included in the kit are easy to understand.	-	-	12 (24.0%)	38 (76.0%)	3.76
8.	Printed exercise questions are easily solved using the kit.	-	-	12 (24.0%)	38 (76.0%)	3.76
9.	Digital exercise questions are easily solved using the kit.	-	-	12 (24.0%)	38 (76.0%)	3.76
10.	Answers to printed exercises are easily referenced in the kit.	-	-	16 (32.0%)	34 (68.0%)	3.68
11.	Answers to digital exercises are easily referenced in the kit.	-	-	15 (30.0%)	35 (70.0%)	3.70
12.	Instructions for exploratory activities using the kit are clear.	-	-	17 (34.0%)	33 (66.0%)	3.66
	Overall mean	-	-			3.74

The final part of the analysis is the "satisfaction" construct, as displayed in Table 7. The feedback received from the respondents regarding their satisfaction in using the VGK for learning orthogonal projection, plans and elevations revealed remarkably high levels of contentment. As indicated by the respondents, the average score for satisfaction was 3.74 for orthogonal projection and an even more impressive score of 3.94 for plans and elevations, underscoring the kit's effectiveness in meeting students' learning needs and preferences.

Moreover, the VGK has proven to motivate students' interest in delving into orthogonal projection, plans and elevations. This is substantiated by the feedback from 40 of the 50 surveyed students, who strongly agreed that the kit piqued their interest in studying these topics. Table 7 highlights that the highest mean score was attributed to item 4, garnering an impressive 3.94. This signified that most students strongly agreed that the kit can significantly enhance their enthusiasm in studying plans and elevations. Furthermore, an overwhelming majority of over 43 students expressed excitement about their ability to visualize objects effectively and actively engage in learning activities using the kit. These findings collectively emphasize the kit's role in fostering satisfaction and enthusiasm among students in studying these geometric concepts as found by the study conducted by Hetmanenko [34] and Lah *et al.* [35].

Usability, in the context of this study, pertains to the degree to which a product effectively serves its intended purpose. It measures how efficiently and effectively users can employ and explore the product to accomplish specific tasks [36], [37]. Based on the comprehensive analysis conducted, the researchers determined that the VGK is highly user-friendly for teachers and students within the school where the study was carried out. Furthermore, it successfully stimulates students' interest, encouraging them to actively engage with

the various forms and concepts presented within the kit. This, in turn, contributes to enhancing students' visualization skills and provides a more meaningful and enriching exposure to the field of geometry.

Meanwhile, Table 8 shows the overall results of the usability assessment conducted on the VGK. The assessment examined the kit's usability by considering the mean score across 4 constructs: usefulness, ease of use, learning convenience, and satisfaction. Remarkably, each construct yielded high mean scores, with a score of 3.74 for usefulness, 3.71 for ease of use, 3.74 for learning convenience, and a notably high 3.87 for satisfaction. The overall mean score for the kit's usability stood at an impressive 3.77. Consequently, this VGK exhibited a high level of usability which could be made as a valuable resource for students in their exploration and understanding of orthogonal projection, plans and elevations topics.

Table 7. Usability results of the VGK for the satisfaction construct

Item	Criteria	Assessment scale				Mean
		Strongly disagree	Disagree	Agree	Strongly agree	
1.	I find it enjoyable to use the kit in learning orthogonal projection.	-	-	13 (26.0%)	37 (74.0%)	3.74
2.	I find it enjoyable to use the kit in learning plans and elevations.	-	-	3 (6.0%)	47 (94.0%)	3.94
3.	The kit enhances my interest in studying orthogonal projection.	-	-	10 (20.0%)	40 (80.0%)	3.80
4.	The kit enhances my interest in studying plans and elevations.	-	-	3 (6.0%)	47 (94.0%)	3.94
5.	I feel excited when I can visualize objects effectively using the kit.	-	-	6 (12.0%)	44 (88.0%)	3.88
6.	I find it enjoyable to engage in exploratory activities using the kit.	-	-	4 (8.0%)	46 (92.0%)	3.92
	Overall mean	-	-			3.87

Table 8. The overall usability assessment results of the VGK

Construct	Mean	Interpretation
Usefulness	3.74	High
Ease to use	3.71	High
Ease of learning	3.74	High
Satisfaction	3.87	High
Overall mean	3.77	High

3.5. Comparison with previous research

The results of this study indicate that the VGK, developed through the ADDIE instructional model, achieved excellent validation outcomes, with both face and content validity reaching a CVI of 1.00. This level of expert consensus is consistent with the findings of Shakeel *et al*. [26] and Spatioti *et al*. [38], who underscored the significance of expert involvement in evaluating the quality and effectiveness of educational tools. Their study demonstrated that educational kits designed with clear learning outcomes and curriculum alignment tend to receive strong endorsement from subject-matter specialists, which reflects the results seen in the present research.

In terms of usability, student responses showed highly positive perceptions across all 4 domains: usefulness, ease of use, ease of learning, and overall satisfaction. These findings echo the work of Oviawe [39], who reported that visual-based, interactive tools enhanced student engagement and motivation, particularly in topics requiring spatial and abstract thinking. The current findings also align with those of Suparman *et al.* [40] and Pentang *et al.* [41], who emphasized that well-designed digital and hybrid educational resources support intuitive learning experiences and facilitate deeper conceptual understanding.

Furthermore, the VGK's design, rooted in constructivist learning theory, provides students with opportunities to actively explore geometric concepts through visual and tactile interaction. This hands-on, learner-centered approach corresponds with the recommendations of Thamae [42] and Phutane *et al*. [43], who highlighted the importance of combining digital and printed learning elements to enhance comprehension in technical subjects such as orthographic projections and elevation views. A unique contribution of the present study is the integration of printed notes, QR-coded multimedia content, and 3D manipulatives tailored specifically for vocational and technical students. This mixed-media approach may offer a more comprehensive learning experience than earlier tools, as reflected in the consistently high satisfaction ratings and ease-of-learning scores. While previous studies emphasized the importance of visualization in geometry learning, many fell short in providing integrated platforms that combine traditional and digital tools. The VGK addresses this gap by offering an engaging and well-balanced resource that fosters both motivation and skill development in spatial reasoning.

4. CONCLUSION

In summary, the development of the VGK has proven to be successful in achieving both satisfactory validity and a high level of usability as perceived by students. These outcomes demonstrate that the fulfilment of the study's objectives with the kit has secured satisfactory validity through the valuable input of 3 experts who participated in the evaluation process. Through the detailed analysis of the CVI values, it has been determined that the VGK's face and content validity have attained an impressive and satisfactory score of 1.00. Hence, it signifies that the kit is well-founded in its design and content. It is an invaluable tool to enhance learning experiences and strengthen students' comprehension of orthogonal projection and planes and elevations.

Furthermore, this kit sharpens students' visualization skills as well as serves as a steppingstone for a more comprehensive mastery of spatial visualization, an integral aspect of geometry. As a practical implication, this kit can be effectively employed in educational settings to facilitate the study of orthogonal projection and planes and elevations, offering students a dynamic and engaging approach to grasp these complex mathematical concepts. However, this study does have its limitations. The usability testing was limited to a sample of 50 Form 3 students from a single school in Kuala Lumpur, which may not fully represent the broader student population. Also, the study only assessed the short-term effectiveness of the kit and did not explore its long-term impact on student learning and retention.

With that in mind, a few recommendations are proposed. Future research should involve a larger and more diverse group of students from different schools and backgrounds to enhance the generalizability of the findings. It would also be beneficial to conduct long-term studies to evaluate how well the kit supports sustained learning. Teachers are encouraged to incorporate the VGK into their classroom practices as a tool to support active learning and improve visualization skills. For further improvement, integrating digital features or interactive technology could make the kit even more versatile, especially in blended or online learning environments.

FUNDING INFORMATION

The authors thankfully acknowledged the financial support provided by Universiti Pendidikan Sultan Idris (2022-0149-107-01: GPUBP) in developing the Visual Geometry Kit.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from the parents or legal guardians of all student participants included in this study. Participation was voluntary, and students were informed about the study's purpose and procedures.

ETHICAL APPROVAL

The research involving human participants has complied with all relevant national regulations and institutional policies, in accordance with the tenets of the Helsinki Declaration. This study was approved by the Ethics Committee of Universiti Pendidikan Sultan Idris.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [NHA], upon reasonable request. The data are not publicly available due to privacy or ethical restrictions involving student participants.

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