

## Development of “OrigamiGo” for enhancing visualization skills based on origami art

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### ABSTRACT

Visualization skills are essential in engineering education, yet many Malaysian students struggle to develop them, which affects their performance in *Grafik Komunikasi Teknikal*, also known as technical drawing. This study evaluated the effectiveness of OrigamiGo, a paper-folding-based teaching module, in improving students' visualization skills. Unlike computer-based tools, OrigamiGo provides low-cost, tactile, hands-on learning experiences that integrate visual and haptic activities. A quasi-experimental design was conducted with 36 tenth-grade students from two secondary schools in Johor, Malaysia. Students' visualization skills were measured using a validated test instrument, and data were analyzed using inferential statistics in SPSS. The experimental group showed significantly greater improvement than the control group, with mean N-gain scores of 57.85 and 20.41, respectively. Paired t-tests showed significant pre-to-post test improvements in both groups. The independent t-test revealed a significant difference in post-test scores, with the experimental group scoring higher than the control group (21.32 vs. 17.29). These findings indicate that OrigamiGo is an effective alternative approach for enhancing visualization skills in technical and vocational education. Future studies may examine its application in broader educational contexts and larger samples.

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## 1. INTRODUCTION

Visualization skills are essential for teaching mathematics and related applications, especially in technical subjects such as technical drawing [1]–[3]. Visualization skills refer to the capacity to mentally manipulate, transform, and interpret visual representations of geometric concepts [4]. This ability is often emphasized in mathematics and engineering education because it is important for perceiving and mentally rotating objects in both two-dimensional (2D) and three-dimensional (3D) spaces [5]. Scholars such as Herrera *et al.* [6] describe visualization skills as the capacity to imagine and mentally manipulate designs from various perspectives, enabling students to envision complex structures before translating them into graphic or verbal forms [7]. Similarly, Dias *et al.* [8] define visualization skills as the ability to mentally manipulate, rotate, and invert objects, which is crucial in fields where spatial reasoning and geometric understanding are

foundational. In engineering and technical fields, visualization skills play a central role, allowing students to mentally interpret and convey information about objects before converting them into physical or graphical forms [9], [10]. This skill is particularly crucial in solving complex technical problems and creating accurate diagrams or blueprints [11], [12]. In the context of technical drawing, for instance, students are expected to represent 3D objects on 2D surfaces, requiring a strong ability to mentally visualize and transform spatial concepts [13]. However, research indicates that Malaysian students generally exhibit low to moderate visualization skills, which affects their comprehension of technical concepts in subjects like technical drawing [14], [15]. Studies by Hsing *et al.* [16] and Wedyan *et al.* [17] have documented specific challenges in visual tasks, such as mentally rotating, combining, and sectioning objects.

Given the critical role of visualization skills, much research has focused on enhancing students' spatial abilities, predominantly through computer-based applications [5], [18]. Recent studies also report that digital visualization tools and interactive platforms can improve spatial understanding, although their effectiveness often depends on access to technological resources and learning infrastructure [8], [12]. However, this study proposes an innovative approach that uses the art of paper folding and manipulation, such as origami and kirigami, which have demonstrated significant potential to enhance visualization and spatial skills. These arts are particularly effective in education for illustrating complex geometric concepts through hands-on, spatial activities [19]. Research indicates that paper folding improves 3D visualization and enhances students' motivation and cognitive engagement [20]. Although traditionally associated with the visual arts, preliminary findings suggest that paper folding can serve as a valuable teaching tool in technical subjects such as technical drawing, particularly for understanding transformations of 3D and 2D representations [21]. Paper-folding activities provide a low-cost and tactile alternative to computer-based visualization, making them suitable for schools with limited technological resources. This approach connects conventional learning practices with digital instructional approaches. In the Malaysian context, this challenge is linked to the 2017 implementation of the *Grafik Komunikasi Teknikal* subject in the secondary school curriculum, which emphasizes the early development of students' spatial visualization skills. The purpose of this study is to develop and evaluate "OrigamiGo", a teaching module based on paper folding and manipulation arts, designed to improve visualization skills in technical and vocational education systems in Malaysia. The module is structured to support students' understanding of technical subjects, with a focus on enhancing their capacity to transform and interpret 3D objects mentally. By combining traditional paper-folding techniques with modern pedagogical goals, this research offers an alternative approach to developing spatial abilities, particularly within technical and vocational education systems in Malaysia.

## 2. THEORETICAL BASIS

The development of OrigamiGo, a visualization module, is rooted in a philosophical approach that recognizes diverse learning styles. As Yang [22] suggests, individuals process information uniquely, and adapting instruction to these preferences can boost its effectiveness. The OrigamiGo module, therefore, draws on the philosophical basis of catering to visual and haptic learning styles, which are essential for enhancing visualization skills in technical and graphic communication subjects [23]–[25]. While visual learners rely on sight, haptic learners benefit from tactile engagement [26]. Previous studies underscore the importance of blending these styles, especially in fields like engineering, to optimize student learning [9], [27]. The integration of visual and haptic learning in OrigamiGo also reflects the principles of inclusive learning, where multiple modes of representation and engagement support diverse learners with different cognitive and sensory preferences [22].

OrigamiGo's development strategy follows a structured approach guided by comprehensive guidelines to ensure alignment with learning objectives. This includes pre- and post-assessments, an introduction, objectives, activity instructions, and a detailed plan for each activity. Following the module development model by Hussain *et al.* [27], OrigamiGo incorporates five practical activities that blend haptic and visual elements. The strategy also integrates Piaget's spatial development theory and McKim's visual thinking model [28], thereby reinforcing the module's conceptual foundation by emphasizing mental manipulation and visualization skills, as illustrated in Figure 1.

In OrigamiGo, Piaget's theory explains how students progressively develop spatial understanding through active interaction with physical objects, while McKim's model highlights the role of visual imagery and transformation in problem-solving processes. The combination of these perspectives allows students to connect physical manipulation with mental visualization, thereby strengthening their spatial reasoning skills. The primary aim of OrigamiGo is to strengthen students' visualization skills, specifically in technical drawing. Key aspects of the module include activities in paper folding and manipulation, which make visualization processes tangible and interactive for students. This approach departs from traditional technical drawing modules that focus on exam-based drawing skills [28]. Instead, OrigamiGo fosters creativity and

problem-solving by encouraging students to produce orthographic drawings and construct 3D objects from 2D perspectives. The module covers core topics such as graphic communication, the art of origami and kirigami, and visualization techniques, enabling students to better understand spatial concepts.

The materials required for OrigamiGo’s implementation are basic yet essential for hands-on engagement. These include A4 paper, A3 cardboard, a drawing board, a T-square, set squares, pencils or pens, scissors, adhesive tape, and a compass. The module also provides access to instructional videos on YouTube via QR codes to guide students through each step of the activities. The content of OrigamiGo is organized into introductory sections, followed by five practical activities. The introductory topics encompass goals, objectives, technical communication, and foundational skills in origami and kirigami. The practical component includes activities such as cube folding, cylinder construction, and creating orthographic drawings that transition from 2D to 3D representations. Each activity is meticulously designed to engage both haptic and visual skills, offering students a comprehensive, interactive experience that builds their visualization proficiency. This structured approach ensures that OrigamiGo is an effective tool for enhancing students’ visualization skills and laying a foundation for more advanced applications in technical subjects. Through both theoretical grounding and practical activities, the module addresses students’ needs and engages them in meaningful, skill-enhancing tasks. The following Figure 2(a) to Figure 2(e) illustrates the five model types created through student OrigamiGo learning activities.

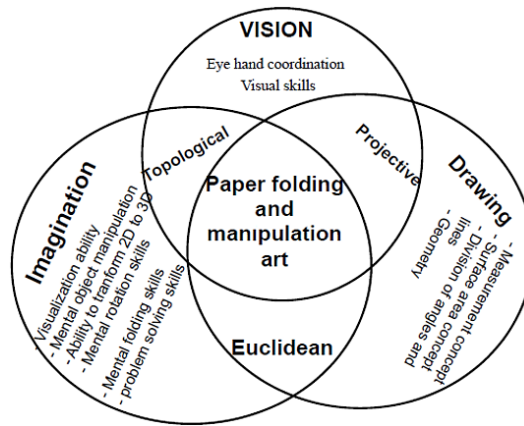


Figure 1. Theoretical framework of OrigamiGo

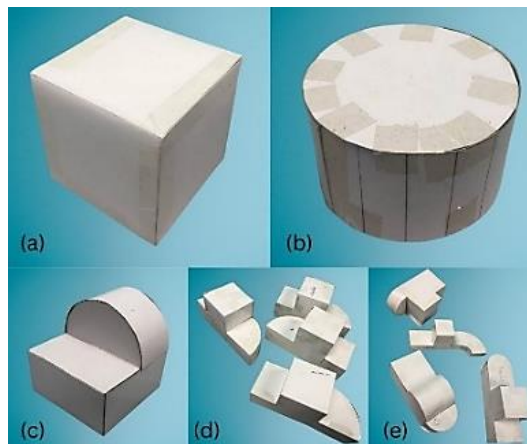


Figure 2. Objects generated by the five activities in OrigamiGo: (a) cube, (b) cylinder, (c) combination of a cube and a cylinder, (d) orthographic projection, and (e) various creative combinations

Figure 2 shows the objects generated by the five activities in OrigamiGo. Figures 2(a) and 2(b) were generated by students following the instructions in the tutorial videos they watched on YouTube. These videos can be accessed via the QR code provided in the module. Students produce Figure 2(c) according to the actual

3D object received by them. The shape, size, and dimensions of this object must be the same as the original 3D object. Meanwhile, Figure 2(d) is a 3D object produced from the information students receive from orthographic drawings, namely the plan view, front view, and side view. Finally, Figure 2(e) is an object that students created using their own creativity, within the guidelines and conditions set in the module. Marking rubric form that has been provided in the module, as illustrated in Figure 3.

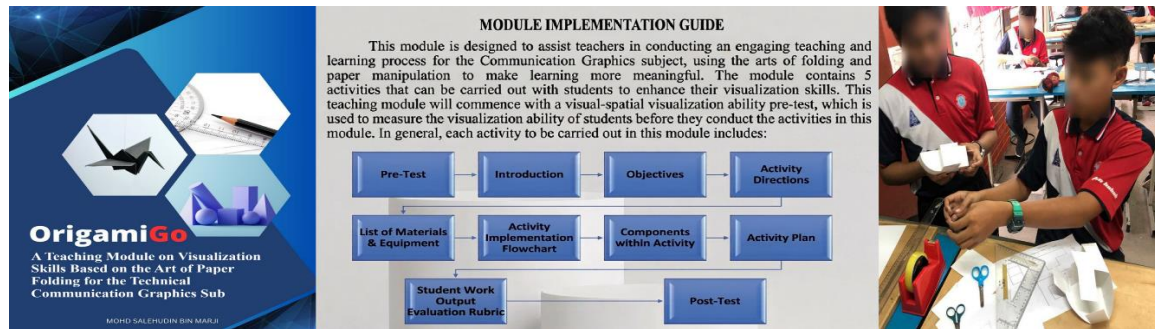


Figure 3. OrigamiGo front cover, content samples, and real in-class visualization teaching activities using OrigamiGo

### 3. METHOD

The method used in this study is a quasi-experimental pretest–posttest control group design. In quasi-experimental studies conducted in educational settings, sample sizes of fewer than 100 respondents are still considered acceptable and are commonly used. The two schools were selected using a convenience sampling approach, based on accessibility and willingness to participate in the study. In this study, the respondents were 36 tenth-grade students from two secondary schools in Johor, Malaysia. A total of 19 students were assigned to the experimental group, which received a visualization-based learning intervention using OrigamiGo. Meanwhile, 17 students were assigned to the control group, which did not receive the OrigamiGo-based visualization learning treatment. The collected data were analyzed using inferential statistics in SPSS. Figure 4 illustrates the study design in greater detail.

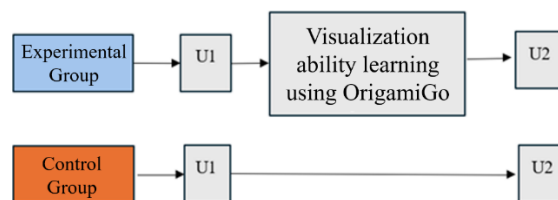


Figure 4. OrigamiGo was used in experimental groups as an additional learning activity

The participants were assigned to two conditions: an experimental group and a control group. Before the intervention, both groups completed an initial assessment (U1) to evaluate their baseline visualization abilities. The experimental group then received instruction incorporating OrigamiGo, while the control group followed regular learning activities. The program lasted six weeks, with two sessions per week, each about 60 minutes. At the end of the intervention, both groups completed a final assessment (U2) to determine changes in visualization performance. All assessments employed validated instruments as shown in Figure 5. The test tools were designed according to visualization skill indicators and technical drawing competencies, reviewed by experts, and pilot-tested before use. Reliability testing produced a Cronbach's alpha coefficient of 0.84, demonstrating strong internal consistency. The impact of OrigamiGo was evaluated by comparing the N-gain results between the two groups. Before data collection, permission was obtained from the participating schools to conduct the study. All participants were informed about the purpose and procedures of the research before it was implemented. Informed consent was obtained from students and teachers involved in the study, and participation was voluntary.

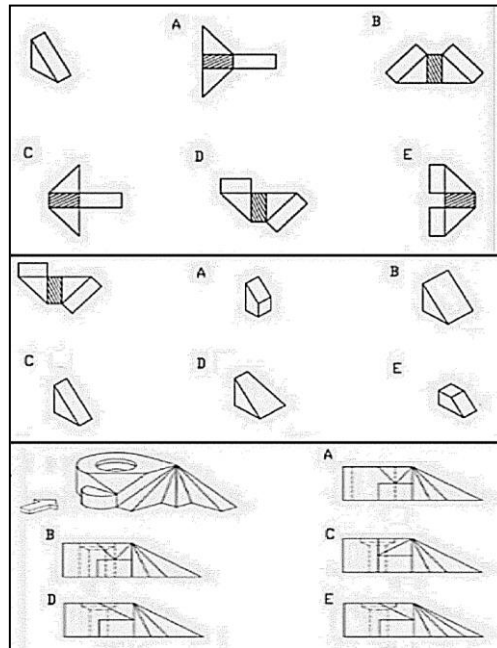


Figure 5. Samples of the visualization skills test instrument, Cronbach alpha=0.84

**4. RESULTS AND DISCUSSION**

**4.1. Results**

The results demonstrate a clear improvement in visualization skills among students who used the OrigamiGo module compared to those who received standard instruction. Pre-test scores were similar between the experimental group (mean=16.53) and the control group (mean=15.29). However, after the six-week intervention, post-test scores showed a marked increase: the experimental group achieved a mean score of 21.32, while the control group reached only 17.29. Statistical analysis confirmed these differences. The paired t-test indicated a significant improvement within each group from pre- to post-test, with a mean increase of 4.79 in the experimental group ( $p < 0.001$ ) and 2.00 in the control group. Furthermore, the independent t-test showed a significant difference in post-test scores between groups, with the experimental group scoring higher by a mean difference of 4.02 ( $p < 0.001$ ), as shown in Table 1.

Effect size analysis using Cohen’s  $d$  revealed a large effect ( $d = 1.70$ ), indicating that the OrigamiGo module had a strong impact on students’ visualization skills. This result demonstrates that the observed differences between the experimental and control groups were statistically significant and educationally meaningful. The N-gain test reinforced the effectiveness of the OrigamiGo module. The experimental group achieved a mean N-gain of 57.85, indicating a substantial improvement, while the control group achieved a mean N-gain of 20.41. Every student in the experimental group showed positive gains, with N-gain values ranging from 11.11 to 100, whereas the control group showed greater variability, including one student with a negative gain and another with no improvement. Table 2 presents the results of paired and independent t-tests conducted to examine differences in students’ visualization skills within and between groups.

Table 1. Testing results

Group	N	Highest	Lowest	Mean	SD	Normality value		Effect size (Cohen’s $d$ )
						Kolmogorov-Smirnov	Shapiro-Wilk	
Pre-test (treatment)	19	23/25	11/25	16.5	3.29	0.2	0.568	1.70
Pre-test (control)	19	25/25	17/25	21.3	2.43	0.2	0.452	
Pre-test (control)	17	20/25	12/25	15.3	2.17	0.2	0.341	
Pre-test (control)	17	21/25	13/25	17.3	2.29	0.2	0.674	

Table 2. Results of paired t-test and independent t-test analyses

Statistical test	Group/comparison	Mean difference	T-value	Degrees of freedom	Sig. (p-value)
Paired t-test	Experimental (pre-test–post-test)	4.79	7.22	18	0.000
Paired t-test	Control (pre-test–post-test)	2.00	3.70	16	0.000
Independent t-test	Post-test (experiment vs. control)	4.02	5.10	34	0.000

The paired t-test showed significant improvements in both groups, with a larger gain in the experimental group (mean difference=4.79, t-value=7.22, degrees of freedom=18, and  $p<0.001$ ) than in the control group (mean difference=2.00, t-value=3.70, degrees of freedom=16,  $p<0.001$ ). The independent t-test also revealed a significant difference in post-test scores between groups (mean difference=4.02, t-value=5.10, degrees of freedom=34, and  $p<0.001$ ), indicating that the OrigamiGo module was more effective than conventional instruction in improving students' visualization skills. To further illustrate the difference in students' performance between the groups, Figure 6 compares the mean pre-test and post-test scores of the experimental and control groups.

Figure 6 presents a comparison of the mean pre-test and post-test scores of the experimental and control groups. Both groups showed improvement after the intervention; however, the experimental group demonstrated a substantially greater increase in scores than the control group. This visual evidence supports the statistical findings that the OrigamiGo module significantly enhanced students' visualization skills.

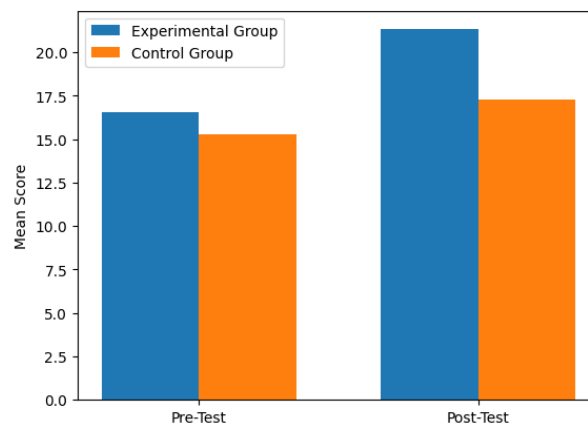


Figure 6. Comparison of pre-test and post-test scores

#### 4.2. Discussion

As mentioned earlier, visualization ability plays a crucial role in student learning, particularly given its importance across disciplines and technical careers [29]. The findings of this research indicate that the OrigamiGo module is effective in enhancing visualization abilities among secondary school learners. The experimental group achieved a markedly higher N-gain score (57.85) than the control group (20.41), demonstrating the module's strong contribution to the development of spatial reasoning and geometric comprehension. Students exposed to OrigamiGo showed not only greater improvements in visualization assessments but also uniform positive progress, with every participant exhibiting measurable advancement. In contrast, the control group showed more varied results, including minimal improvement and score declines. These outcomes suggest that OrigamiGo is a practical and powerful resource for strengthening spatial skills in educational settings. Comparable pre-test results between both groups confirm that students began the study with similar levels of visualization ability. Although the control group showed some improvement, likely due to traditional instruction, the magnitude of progress was notably lower than that of the experimental group. Furthermore, the large effect size (Cohen's  $d=1.70$ ) reflects a meaningful educational impact rather than a purely statistical difference. The superior gains observed in the experimental group may be linked to the combination of visual and hands-on learning experiences, which promote more profound spatial understanding.

These findings suggest that integrating hands-on paper-folding activities into technical drawing instruction can be a practical and effective way to enhance students' spatial visualization skills. These findings are consistent with constructivist perspectives, particularly Piaget's theory of cognitive development, which emphasize that students build understanding through active engagement and hands-on (sensorimotor) learning experiences [28], [30]. To enhance students' visualization skills, teachers can utilize a variety of instructional methods, from conventional approaches to computer-based technology [31]–[33]. However, not all schools have adequate computer labs. In such situations, OrigamiGo offers an effective way to develop visualization skills using simple, affordable materials that are easy to find. The tangible improvement in test scores achieved by the experimental group highlights the accessibility and practicality of OrigamiGo, even in resource-limited settings. Although the use of paper folding and manipulation in this module is traditional—relying only on paper, adhesives, and manual drawing and sketching—it still incorporates technology through video tutorials

that students can access via YouTube for two module activities. This combination of conventional and technological elements appeals to today's tech-savvy students, offering a modernized approach to learning. The post-test results for the experimental group (mean score of 21.32) further emphasize how these integrated activities bridge gaps between traditional and contemporary learning methods. OrigamiGo also brings a fresh perspective to the typical 2D drawing process. Through module activities, students gain hands-on experience creating 3D objects, thereby gaining a better understanding of the 3D forms they encounter only in drawings. This experiential learning aligns with the 4.79 mean increase in test scores observed in the experimental group, suggesting that tactile engagement enhances spatial comprehension and visualization skills. Furthermore, OrigamiGo not only improves visual skills but also introduces students to concepts such as geometry, problem-solving, fine motor skills, teamwork, and motivation through a student-centered learning approach. OrigamiGo promotes inclusivity by adopting both haptic and visual learning styles, widening its applicability across different learning preferences. The consistently positive N-gain results among participants in the experimental group indicate that the module effectively supports diverse learners, making it a viable option for classrooms with varying learning needs. This research has several limitations, including a small sample size, participants drawn from a single geographic area, and the exclusion of gender-based analysis due to unequal group representation.

In the Malaysian context, it is worth noting that *Grafik Komunikasi Teknikal* subjects were only introduced in 2017. Further research is essential to refine the content and teaching methods, enabling students to gain more benefits and achieve higher performance in this area. Increasing the sample size and involving students from a wider range of schools and backgrounds would improve the generalizability of the results to broader learner populations. Analyzing the module's impact by gender could also provide insights into how visualization skills develop differently among male and female students, as this study did not include such an analysis due to an unbalanced sample. Increasing the number of questions in the visualization skills test could yield more robust data, as only 25 were provided. Applying paper folding and manipulation to other topics, such as isometric and oblique drawings and polygons, could offer students broader opportunities to apply visualization skills. Given that the OrigamiGo module was highly effective at improving 3D understanding, its application in these areas could further enhance students' spatial reasoning across the broader curriculum. Future studies could also consider conducting qualitative analyses to support quantitative findings. Researchers could gather qualitative insights by interviewing teachers and students involved in the module to supplement quantitative data. For example, understanding how students perceive the transition from 2D to 3D representations and their engagement with OrigamiGo activities could shed light on the motivational and cognitive benefits observed. This research shows promising results for secondary school students, but its application in technical and vocational contexts could further validate its utility in developing industry-relevant skills. This study implies that further studies with larger samples on the same research topic are needed. Future studies may also consider combining quantitative data with qualitative approaches, such as interviews with students and teachers, to understand students' learning experiences better.

## 5. CONCLUSION

The results of this research indicate that the OrigamiGo module produces a strong positive effect on students' visualization abilities, particularly within technical and vocational education settings. By integrating the traditional practice of paper folding with modern instructional approaches, OrigamiGo effectively connects abstract theory with real-world application. Its experiential learning design encourages both cognitive and physical interaction with spatial ideas, leading to observable gains in students' capacity to manipulate and interpret three-dimensional forms. The substantial difference in N-gain scores between the experimental group (57.85) and the control group (20.41) highlights the module's success in strengthening spatial reasoning, geometric comprehension, and associated skills. Comparable pre-intervention results and statistically significant t-test outcomes confirm meaningful learning progress, supported by a large effect size (Cohen's  $d=1.70$ ). Collectively, these findings suggest that OrigamiGo supports the advancement of higher-level cognitive skills essential for solving technical and spatial problems.

These findings suggest that OrigamiGo can be positioned as a low-cost and scalable instructional intervention, particularly suitable for schools with limited technological resources. OrigamiGo's accessibility and simplicity make it a valuable tool for resource-limited educational settings, offering a cost-effective alternative to computer-based visualization tools. Its integration of haptic and visual learning styles promotes inclusivity. It addresses diverse learner needs, making it particularly relevant for Malaysian schools, where the subject of *Grafik Komunikasi Teknikal* was introduced into the Malaysian curriculum in 2017. From a policy perspective, OrigamiGo could be integrated into Malaysia's vocational and technical curriculum to support students' spatial and visualization skills. The module's success in enhancing fine motor skills, teamwork, and problem-solving abilities further demonstrates its potential as a comprehensive educational resource. Future research should explore the module's application across broader contexts. By refining and extending the

OrigamiGo module, educators can better prepare students for the spatial and technical challenges of both academic and professional environments. Ultimately, OrigamiGo represents a promising step forward in advancing visualization skills within the technical and vocational education landscape.

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### 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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Nor Aisyah Che Derasid	✓		✓	✓			✓			✓	✓		✓	✓
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C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

### CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

### DATA AVAILABILITY

The data produced and examined in this research can be accessed by contacting the corresponding author, [MSM], upon an appropriate request.





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