ASSESSMENT OF THE INTERACTIVE SPATIAL INTELLIGENCE MODULE FOR 1ST YEAR ARCHITECTURE STUDENTS

Adolph Vincent E. Vigor[1*], Sarah O. Namoco[1], Mohd Hafizal Bin Mohd Isa[2]
[1]University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines
[2]University Sains Malaysia,11800 Gelugor,Penang,Malaysia
[*]Corresponding author's email: adolphvincent.vigor@ustp.edu.ph

ABSTRACT. *Spatial intelligence is important in design-based disciplines like architecture, but it is not given much attention despite its influence on students' performance. Low spatial intelligence is also a barrier to success in STEM disciplines. However, spatial intelligence is malleable and could be improved through interventions. For this reason, a web-based interactive spatial intelligence module is essential to enhance the spatial understanding of freshmen architecture students. This study aimed to assess the developed web-based interactive spatial intelligence module intended for freshmen architecture students. The module consists of activities involving mental rotation and spatial visualization using the web version of SketchUp over a span of 9 weeks. Ten lecturers and 39 freshmen architects assessed the module using the instrument adopted from Mercado. The parameters for evaluation were content quality, technical quality, and instructional quality. The results of the data analysis indicated that the experts and students strongly agree on the acceptability and usability of the web-based interactive spatial intelligence module. These statistical results from experts and students are further supported by the verbatim of both groups that show interest and support for the developed module. In conclusion, both experts and students strongly agree with the indicators of the instrument in terms of content quality, technical quality, and instructional quality. It is recommended to improve the module content by adding topics from designs 3 to 10.*

Key Words: Architectural Education, Interactive Spatial Intelligence Module, Module Assessment, Mental Rotation, SketchUp

1. INTRODUCTION

Spatial intelligence refers to the capacity to form mental images and forms to solve problems in space [1]. It is also defined as the ability to represent and imagine ideas visually. A high level of spatial intelligence capacitates an individual to orient themselves in the context of three dimensions [2]. Hence, spatial intelligence is considered an important skill for those in the field of STEM or more specifically the field of architecture [3].

Previous studies reported that there is a profound relationship between spatial intelligence and creativity, making it a vital dimension in architectural design [4]. Thus, scholars suggest that it is important for architects to be able to interpret two-dimensional ideas into three-dimensional constructs [5]. With this, past and present studies suggest that having a higher level of spatial intelligence is a good predictor of success in STEM-related disciplines such as architecture [6]. Therefore, it is important to help architectural students develop this type of intelligence.

The researcher, in his fifteen years of experience as an architect, had observed that architecture students and interns learn faster when given visual instructions or lectures. This observation is supported by previous studies. For example, in the study of Gumilar & Nandi [7] on the level of spatial intelligence of senior high school students in Indonesia, they related spatial intelligence with a person's competence in comprehending the environment which surrounds them and how an individual orients himself in this type of setting. They expressed the importance of spatial intelligence in understanding geography and they found that most senior high school students in Indonesia have relatively high levels of spatial intelligence.

Another research on the aspect of spatial intelligence in the Czech Republic was conducted by Prokýšek & Štípek [8] on university students at Charles University, Prague. Their study explored the present state of mental rotation and cutting potential of students in the university when correlated to gender, age, and study program the students belong to. The authors found that mental rotation ability is dependent on age. This means that mental rotation activities have a more profound effect on younger individuals therefore interventions with regard to the improvement of spatial ability have more efficacy at the earliest possible time.

The research study conducted by Ardini & Handini [9] explored the influences of visual-spatial intelligence and instructional methods in teaching early reading abilities. They found that the introduction of visual techniques in teaching students increased their ability in learning how to read. This means that increased levels of spatial intelligence have an impact on the linguistic and reading abilities of students.

Visual-Spatial Intelligence has also been found to have correlations with athletic abilities. The study of Millard et al. [10], revealed that a broad range of factors could affect visual-spatial intelligence and vision that could contribute significantly to the processes and systems related to the assessments of the decision-making skills of different athletes. This could mean that a competitive edge for athletes could be found in the investigation of spatial intelligence and its correlation to athletic ability.

Studies cited above prove that spatial intelligence is an essential skill for a student to thrive. In the context of architecture students, it is a necessity that they acquire and develop certain skill sets to be successful when they take the licensure examination or when practicing architecture after graduation. The most important technical skill identified by the students was the ability to do manual drafting of perspectives and floor plans followed by possessing three-dimensional imagination and an aptitude for computer-aided design software [11].

The good thing is that spatial intelligence could be improved and can be developed through the use of interventions and training [12]. Relevant literature suggests that these interventions have more efficacy in the early stages of a program compared to being implemented at the latter stages of a student's study when it becomes too late or the student just quits studying [13]. Most of the instructional materials developed to address spatial intelligence are often conventional in nature [14] and are not responsive to the needs of genZ students who are more exposed to technology [15]. This means that having a three-dimensional image is important in architecture as initially discussed by the researcher. However, the researcher as an architect, believes that having a three-dimensional imagination is the product of an awakened higher level of spatial intelligence which could influence the way students solve design problems.

To address this need of architectural students to help them develop their spatial intelligence, the researcher developed an innovative, web-based Interactive Spatial Intelligence Module (ISIM). However, before this ISIM can be implemented, its acceptability evaluation must be established first to ensure that its usability will warrant its purpose in helping freshmen architecture students develop their spatial intelligence. This study seeks to determine the acceptability of the web-based ISIM in terms of content quality, technical quality, and instructional quality.

Literature Review

The acceptability of instructional materials comprised of three areas: content, technical and instructional qualities. In the Interactive Spatial Intelligence Module (ISIM), content quality is important because it should be aligned with the activities of the Architectural Design 2 syllabus in the Architecture program. Moreover, it is also essential that the competencies included in the ISIM are aligned with the CHED Memorandum Order Circular 61 which is the program standard for the architecture curriculum. Its content should also be of high quality to encourage students to study and learn more about the course [6]. In terms of technical quality, this dimension is important in the module because the students are Gen Z learners who are quite well-versed in technology [15]. To keep the students interested in the lessons, the technical dimension of the module needs to be sufficient for the new generation of learners. In relation to the two previous dimensions, the instructional quality of the module is important because a high level of instructional quality correlates to the excellent performance of students [16].

2. METHODOLOGY

2.1 Research Design

This study utilized the descriptive research design which, according to Lunenberg and Irby [17], is a design that describes phenomena in our world. This type of design is appropriate for the study because this study aims to determine the level of acceptability of the Interactive Spatial Intelligence Module.

2.2 Research Setting

The study is conducted at a State University in Northern Mindanao offering the Bachelor of Science in Architecture program. The development and assessment of the module took place in Cagayan de Oro City in a face-to-face context with the Architectural Design experts.

2.3 Participants of the Study

The participants of this study are composed of three phases: eight language experts who pre-tested the question items to ensure that it is comprehensible to the actual participants (Table 1). Another set of participants was eight Architectural Design experts to evaluate the content validity of the ISIM (Table 2). Thereafter, 37 freshmen architecture students were employed for the reliability testing of the instrument. Finally, ten Architectural Design experts (Table 3) and 39 freshmen architecture students were recruited to assess the acceptability of the ISIM. All of the expert participants were purposively recruited, and the students were randomly recruited based on pre-determined inclusion or exclusion criteria (Table 4).

Table-1: English Experts Profile

Expert	Educational Qualification	Teaching Experience	Department	Sex
1	PhD	21 years	English	F
2	MS	18 years	English	M
3	MS	4 years	English	M
4	MS	4 years	English	F
5	MS	4 years	English	F
6	MS	4 years	English	F
7	MS	4 years	English	F
8	MS	4 years	English	F

Table-2: Design Experts Profile for Content Validity

Expert	Educational Qualification	Industry Experience	Teaching Experience	Sex
1	PhD	21 years	9 years	M
2	MS	15 years	12 years	F
3	MS	20 years	4 years	M
4	MS	20 years	4 years	M
5	MS	8 years	4 years	M
6	MS	5 years	4 years	M
7	MS	5 years	4 years	M
8	MS	5 years	4 years	M

Table-3: Design Expert Evaluators Profile

Expert	Educational Qualification	Industry Experience	Teaching Experience	Sex
1	PhD	21 years	9 years	M
2	MS	15 years	12 years	F
3	MS	20 years	4 years	M
4	MS	20 years	4 years	M
5	MS	8 years	4 years	M
6	MS	5 years	4 years	M
7	MS	5 years	4 years	M
8	MS	5 years	4 years	M
9	BSc	5 years	4 years	M
10	BSc	5 years	4 years	F

Table-4 Participant Inclusion and Exclusion Criteria

Activities	Inclusion and Exclusion Criteria
Pre-testing of Research Instrument	a) Language Expert b) Have at least one year of teaching experience in the language courses
Content Validity Testing	a) Lecturers who are experts in the Architectural Design 2 course b) Must have been teaching the course for at least two years
Reliability Testing Module Assessment	a) 39 Students: a. Enrolled in the university under study b. Freshman architecture student c. Not part of the actual study b) Ten faculty Experts: a. Lecturer or professor in the architecture or civil engineering departments b. Must have taught Architectural Design subjects in their respective fields c. Must have at least 3 years of teaching experience d. Must have at least 4 years of industry experience

2.4 Research Instrument

The research instrument used in this study is adapted from the work of Mercado [18]. It has three major sections namely: content quality, technical quality, and instructional quality. The question items in each parameter were measured using a five-point Likert scale. The range of values of the scale is shown in table 5.

Table 5. Range of values for interpreting data analysis results

Scale	Description	Interpretation
1	Totally Disagree	The ISIM is totally unacceptable and unusable to suit its purpose.
2	Disagree	The ISIM is somewhat unacceptable and unusable to suit its purpose
3	Neutral	The ISIM is neither acceptable nor unusable for its purpose.
4	Agree	The ISIM is somewhat acceptable and usable for its purpose.
5	Totally Agree	The ISIM is highly acceptable and usable to suit its purpose.

Before the instrument was disseminated for the actual study, a pre-testing was conducted to ensure that the items are comprehensible to the actual respondents. The items and content were reviewed by eight experts from the English department to make sure they could be understood by its intended audience. The profile of the experts is shown in Table. For content validation, six experts is sufficient but the number should not exceed ten [19]. Results of the Content Validity Index as evaluated by eight experts revealed a CVI value of 1.0. A CVI of 1.0 is acceptable with eight experts' evaluations [20].

The reliability analysis of the research instrument was conducted using Cronbach's Alpha. The respondents were 37 freshmen who were randomly selected. Table 6 shows the results of the reliability analysis. the acceptable range of reliability test results is 0.70 but not more than 0.95 [21]. It can be observed that the lowest value is 0.840 and the highest value is 0.937. This means that the parameters for assessing the acceptability of ISIM satisfied the reliability criteria [21].

Table 6: Reliability Analysis

Sections	Cronbach's Alpha
Content Quality	0.903
Technical Quality	0.840
Instructional Quality	0.872
Overall Instrument	0.937

2.5 Data Collection

Prior to the collection of data, the researcher first obtained permission from the university officials to conduct the study in the architecture department in accordance with the Data Privacy Act of 2012. For the data collection procedure, Table 7 summarizes the activities conducted for each stage of this study.

Table 7. Data Collection Procedure

Activities		Data Collection
Pre-testing of Research Instrument		Recruited eight language experts through purposive sampling to ensure that the items in the instrument are comprehensible to the respondents of the study.
Content Validity Testing		Recruited eight Architectural Design experts through purposive sampling for the content validity testing of the instrument.
Reliability Testing		Randomly recruited 37 freshman architecture students that are not part of the actual study to assess the module based on the instrument. The students were contacted through their Architectural Design instructor. They were introduced to the ISIM and they had actual experience learning from the ISIM.
Module Assessment		Recruited ten Architectural Design experts through purposive sampling to assess the module based on the instrument. Recruited 39 freshman architecture students that are not part of the actual study to assess the module based on the instrument. The students were contacted through their Architectural Design instructor. They were introduced to the ISIM and they had actual experience learning from the ISIM.

2.6 Data Analysis

The data gathered from the 10 Architectural Design expert evaluators and 39 1st year architecture students for the assessment of the ISIM were analyzed through the Jamovi statistical software [22]. The means and standard deviation of the items in the instrument were then gathered, coded, and analyzed using the range of values in table 1.

2.7 Development of the Module

The content of the module is based on the approved syllabus for the Architectural Design 2 course of the Bachelor of Science in Architecture program. The module design is based on three aspects of spatial intelligence namely spatial visualization, spatial orientation, and mental rotation [23]. These dimensions of spatial intelligence are integrated into the module by embedding the web version of the program SketchUp to view and analyze 3D objects and by adding rotating 3D objects of spaces and different residential building types in the module. For example, a rotating spiral staircase is shown to students in the first week of the module as shown in figure 1. And the objects shown become more intricate as the week progresses. For example, a full 3D of a residential mansion is shown in figure 2 for week 9.

The development of the interactive module will be based on Nearpod as its core, SketchUP will be embedded in its functionality as a tool for 3D modeling, design, and other activities in improving the spatial understanding of students. Other functionalities such as Google Meets, Google Classroom, and Google Docs will be added to enhance the learning experience of students. The interactive module will cover 9 weeks and will complement the Architectural Design 2 subject of the department that has 4 units credits with 1-hour lecture and 3 hours of a studio in the approved syllabus.

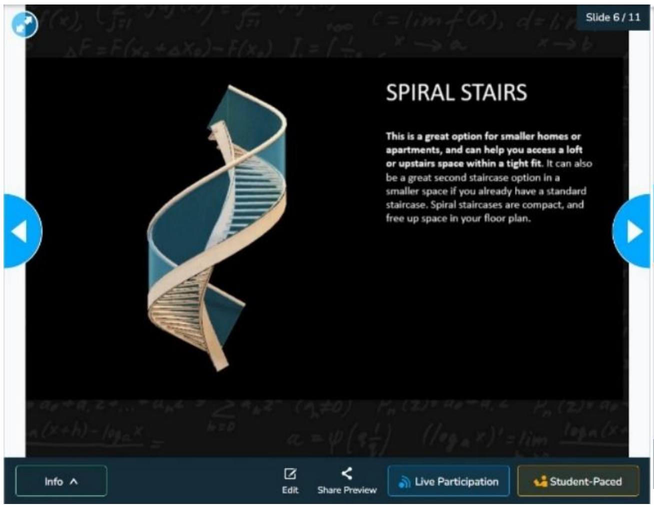

Figure-1: Rotating Spiral Staircase Week 1

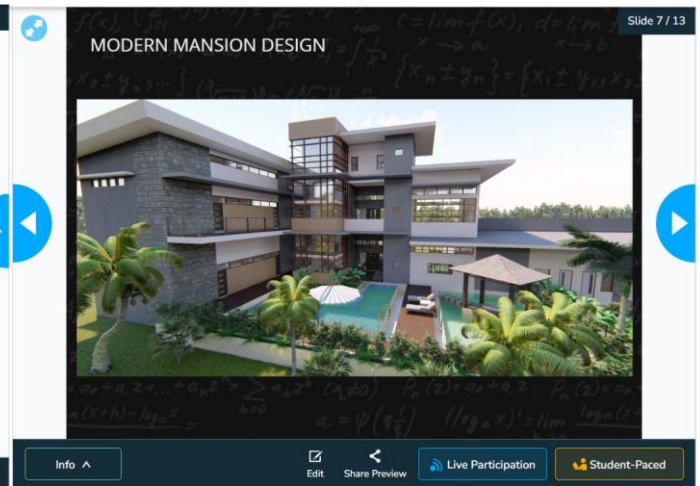

Figure-2: Modern Mansion Week 9

3. RESULTS AND DISCUSSION

3.1 Assessment of Content Quality Criterion

A high level of content quality is important for the student's learning [25]. As reflected in table 7, the experts strongly agree (M= 4.62, SD=0.539) with the indicators of the instrument. The results also suggest that the students concur with the experts' assessment (M=4.77, SD=0.419) of the ISIM. Overall, the results of table 6 indicate that the use of 3D rotating images and objects makes it easier for architecture students to understand and use the module. It is important to note that according to Suh & Cho [26], rotating 3D images and objects is important in the improvement of spatial intelligence because it develops the mental rotation skills of students. Information presented in 3D format is easier absorbed by students since it is condensed [27].

Table 7- Content Quality Assessment

Content Quality Items	Student Assessment			Design Expert Assessment			Average		
Indicator	Mean	SD	Interpretation	Mean	SD	Interpretation	Mean	SD	Interpretation
The content quality is scientifically accurate and adequate.	4.69	0.521	SA	4.55	0.522	SA	4.62	0.5215	SA
Emphasize active learning.	4.79	0.409	SA	4.82	0.405	SA	4.805	0.407	SA
Content of each activity is relevant to the learnings.	4.79	0.409	SA	4.55	0.820	SA	4.67	0.6145	SA
It is well organized.	4.85	0.366	SA	4.55	0.820	SA	4.70	0.593	SA
It evaluates student learning as stated in the objectives.	4.69	0.468	SA	4.18	1.168	SA	4.435	0.818	SA
It allows for the development of multiple intelligences.	4.87	0.339	SA	4.27	1.191	SA	4.57	0.765	SA
Topics are supported by illustrations and tasks suited to students.	4.79	0.409	SA	4.91	0.302	SA	4.85	0.3555	SA
It is aligned to the curriculum	4.74	0.442	SA	4.82	0.405	SA	4.78	0.4235	SA
The contents are free from ethnic, gender and other stereotypes	4.79	0.409	SA	4.91	0.302	SA	4.85	0.3555	SA
Section Mean	4.77	0.419	SA	4.62	0.659	SA	4.695	0.539	SA

Furthermore, the experts' feedback is in line with the findings on the statistical data because they agree with the content and recommended the development of more modules in the future. The experts narrated that:

Expert 1: *"To provide more modules in the future that is important to space planning."*
Expert 2: *"The module is cohesive with the design plates of the subject."*
Expert 3: *"It is necessary for the field of architecture."*
Expert 4: *"3D interpretation is very important for students (as future designers and visualizers) to understand more space planning in architecture."*

It is also further stated by the experts that the use of rotating images and 3D objects enhances the learning experience of students, especially with the use of SketchUp to investigate scaled architectural components such as different stair types and residential building types. This further highlights the educational potential of the use of SketchUp and confirms past studies that show how the software aids in helping improve the spatial perception of students who have used the software [28]. It is also important to note that the integration of technology in teaching removes classroom restrictions and results in more effective learning [29].

In conjunction with the expert review, thirty-nine 1st year architecture students were randomly selected to evaluate the module based on similar parameters of the instrument but were modified to reflect the view of students that will utilize the module.

Furthermore, the student's feedback on the content quality supports the statistical data. The students' narratives are the following:

Student 1: *"Content is correlated to my syllabus."*
Student 3: *"Very informative and helpful to develop my skills."*
Student 4: *"The content is relevant and helpful for the students."*
Student 7: *"I like how the content gave me a clear idea about the lesson, especially the spatial intelligence. I was able to visualize more."*
Student 8: *"The contents are simple and easy to understand."*
Student 9: *"It has a lot of contents that are helpful for this subject and my course."*

Students clearly highlight the significance of the module and how useful it is for students in learning the lessons for Architectural Design 2. This also supports the findings in various literature that the use of supplemental images and 3D are helpful to students in understanding the lessons that need to be learned [8, 30–36].

3.2 Assessment of Technical Quality Criterion

The technical quality of the learning material is important since the module caters to Gen-Z students that enjoy and are much more exposed to technology [12]. The following table 8 presents the technical quality of the developed module the experts strongly agree that the module is easy to understand, and the graphics are excellent (M=4.52, SD=0.557).

It is also further stated by the experts that the use of rotating images and 3D objects enhances the learning experience of students, especially with the use of SketchUp to investigate scaled architectural components such as different stair types and residential building types. This further highlights the educational potential of the use of SketchUp and confirms past studies that show how the software aids in helping improve the spatial perception of students who have used the software [34]. It is also important to note that the integration of technology in teaching removes classroom restrictions and results in more effective learning [29]

.

Table 8-Technical Quality Assessment

Technical Quality Items	Students			Architectural Design Experts			Average		
Indicator	Mean	SD	Interpretation	Mean	SD	Interpretation	Mean	SD	Interpretation
The module is easy to understand.	4.64	0.537	SA	4.73	0.467	SA	4.685	0.502	SA
The module allows the learner to control the pace of learning.	4.69	0.468	SA	4.45	0.522	SA	4.57	0.495	SA
The graphics are excellent.	4.87	0.339	SA	4.45	0.522	SA	4.66	0.4305	SA
Intended users can easily and independently use the module.	4.69	0.468	SA	4.64	0.505	SA	4.665	0.4685	SA
The language is clear, concise and motivating.	4.72	0.456	SA	4.45	0.688	SA	4.585	0.572	SA
The terms are well-defined.	4.74	0.442	SA	4.45	0.522	SA	4.595	0.482	SA
Topics are presented in a logical and sequential manner.	4.74	0.442	SA	4.36	0.674	SA	4.55	0.558	SA
Section Mean	4.71	0.470	SA	4.52	0.557	SA	4.615	0.5135	SA

Table 8 also reflects the students' assessment of the module based on the technical quality of the interactive spatial intelligence module. It can be seen in the table that the students strongly agree on the indicators of the instrument (M=4.71, SD=0.470).

Furthermore, the student's feedback on the technical quality support the statistical data. The students' narratives are the following:

Student 2 *“It is a good platform since it encourages students like me to think beyond my imagination.”*
Student 6: *“I understand the lessons better in 3D.”*
Student 7: *“It gives clear visualization of an object such as the stairs that was presented.”*
Student 11: *“Easy to understand the lesson because of the 3D detail presentation.”*

Student 11: *"It is very useful especially to us architecture students, it makes it easy to access any website of the university."*

Students vary in their level of spatial intelligence and exposure to spatial-related tasks before joining the architecture program. Therefore to address this issue it is important to integrate interventions in spatial intelligence at the earlier stages because it has a better impact compared to implementing it at the latter stages of the course [37]. Another issue that needs to be addressed regarding the spatial intelligence enhancement of architecture students is that the instructional materials developed for spatial intelligence are more conventional in nature [11] and would be less responsive to the Gen-Z students that are more exposed to technology [12]. The good thing is that traditional methods of teaching Architectural Design could be complemented by strategies for developing spatial intelligence [35].

Assessment of Instructional Quality Criterion

Access to materials that are of high quality is critical to instruction and promotes the excellent performance of students [25]. The results in table 9 pertaining to the instructional quality of the developed module suggest that the experts strongly agree that the module (M=4.57, SD=0.645). This means that the experts are aware of the importance of the module as an aide for students to develop their spatial understanding and awareness and its importance as a supplement for architecture especially if it could be implemented at the curriculum level [38].

Table 9- Instructional Quality Assessment

Instructional Quality Items	Student Assessment			Design Expert Assessment			Average		
Indicator	Mean	SD	Interpretation	Mean	SD	Interpretation	Mean	SD	Interpretation
It provides feedback on the student’s answer.	4.56	0.552	SA	4.27	0.786	SA	4.415	0.669	SA
The module is of high educational value.	4.85	0.366	SA	4.91	0.302	SA	4.88	0.334	SA
It is a good supplement to the curriculum.	4.87	0.339	SA	4.64	0.505	SA	4.755	0.422	SA
It addresses the needs and concerns of students.	4.74	0.442	SA	4.73	0.467	SA	4.735	0.909	SA
The module facilitates collaborative and interactive learning.	4.82	0.389	SA	4.55	0.688	SA	4.685	0.5385	SA
Integrates students’ previous experiences.	4.82	0.389	SA	4.09	1.221	A	4.455	0.805	SA
The module supports in solving quizzes and design plates in architecture..	4.77	0.427	SA	4.55	0.688	SA	4.66	0.5575	SA
It reflects current trends in architectural studio instruction.	4.79	0.409	SA	4.64	0.505	SA	4.715	0.457	SA
The graphics and colors used are appropriate for the instructional objectives.	4.85	0.366	SA	4.27	0.786	SA	4.56	0.576	SA
Section Mean	4.79	0.409	SA	4.91	0.302	SA	4.85	0.3555	SA

Looking into table 9, the means of the various indicators on instructional quality clearly indicate that the students strongly agree with the indicators in the instrument (M=4.79, SD=0.409).

Furthermore, the student's feedback on the instructional quality supports the statistical data. The students' narratives are the following:

Student 5: *“For me, as a beginner in architecture, this module will definitely help in my journey and hopefully would make me better.”*
Student 10: *“This module is really helpful for my design plates.”*

CONCLUSION

In terms of content, technical and instructional quality. The experts strongly agree that the interactive spatial intelligence module is of high educational value and meets the indicators of the adopted instrument. It could also be ascertained from the data that the experts believe that the spatial intelligence of the students could be improved through the module. The statistical data also suggests that the students also strongly agree that the developed Interactive Spatial Intelligence Module met all the parameters of the assessment instrument, and this is also supported by the verbatim gathered from them.

RECOMMENDATION

Further study is recommended on improving the module content by adding higher level architectural design considerations such as design 3 to design 10.

REFERENCES

[1] S. Türkmenoglu Berkan, S. K. Öztas, F. I. Kara, and A. E. Vardar, “The Role of Spatial Ability on Architecture Education.,” *Des. Technol. Educ. an Int. J.*, vol. 25, no. 3, pp. 103–126, 2020.

[2] C. Dawson, “Tackling limited spatial ability: lowering one barrier into STEM?,” *Eur. J. Sci. Math. Educ.*, vol. 7, no. 1, pp. 14–31, 2021, doi: 10.30935/scimath/9531.

[3] M. S. Khine, *Visual-spatial Ability in STEM Education*. 2016.

[4] J. C. Mercado, “Development of Laboratory Manual in Physics for Engineers,” *Int. J. Sci. Res.*, vol. 9, no.

10, pp. 200–210, 2020, doi: 10.21275/SR201002120011.

[5] P. Carter, *IQ and Aptitude Tests*, vol. 53, no. 9. KoganPage, 2011.

[6] C. Carbonell-Carrera and J. L. Saorin, "Virtual learning environments to enhance spatial orientation," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 14, no. 3, pp. 709–719, 2018, doi: 10.12973/ejmste/79171.

[7] J. Suh and J. Young, "Linking spatial ability , spatial strategies , and spatial creativity : A step to clarify the fuzzy relationship between spatial ability and creativity," *Think. Ski. Creat.*, vol. 35, no. September 2019, p. 100628, 2020, doi: 10.1016/j.tsc.2020.100628.

[8] Y. E. Yaz, "The Relationship Between Cognitive Style and Visual Spatial Intelligence Of First Year Architectural Students," *Kastamonu Educ. J.*, vol. 25, no. 2, pp. 805–820, 2017.

[9] I. M. González-Treviño, G. M. Núñez-Rocha, J. M. Valencia-Hernández, and A. Arrona-Palacios, "Assessment of multiple intelligences in elementary school students in Mexico: An exploratory study," *Heliyon*, vol. 6, no. 4, 2020, doi: 10.1016/j.heliyon.2020.e03777.

[10] Y. Li, Y. Yang, Z. Yao, and G. Xu, "Virtual 3D environment for exploring the spatial ability of students," *Virtual Real. Intell. Hardw.*, vol. 2, no. 6, pp. 556–568, 2020, doi: 10.1016/j.vrih.2020.08.001.

[11] A. Ben Chikha, A. Khacharem, K. Trabelsi, and N. L. Bragazzi, "The Effect of Spatial Ability in Learning From Static and Dynamic Visualizations: A Moderation Analysis in 6-Year-Old Children," *Front. Psychol.*, vol. 12, no. June, pp. 1–8, 2021, doi: 10.3389/fpsyg.2021.583968.

[12] A. Szymkowiak, B. Melović, M. Dabić, K. Jeganathan, and G. S. Kundi, "Information technology and Gen Z: The role of teachers, the internet, and technology in the education of young people," *Technol. Soc.*, vol. 65, no. January, 2021, doi: 10.1016/j.techsoc.2021.101565.

[13] Y. H. Gumilar and N. Nandi, "The Student's Spatial Intelligence Level in Senior High School," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 145, no. 1, 2018, doi: 10.1088/1755-1315/145/1/012094.

[14] M. Prokýšek and J. Štípek, "Spatial Intelligence of University Students," *Procedia - Soc. Behav. Sci.*, vol. 217, pp. 372–376, 2016, doi: 10.1016/j.sbspro.2016.02.105.

[15] P. Ardini and M. Handini, "The Influence of Instructional Method, Visual Spatial Intelligence, and School Readiness on Early Reading Abilities," *J. Sci. Res. Reports*, vol. 17, no. 4, pp. 1–22, 2018, doi: 10.9734/jsrr/2017/38737.

[16] L. Millard, I. Shaw, G. J. Breukelman, and B. S. Shaw, "Factors affecting vision and visio-spatial intelligence (Vsi) in sport: A review of the literature," *Asian J. Sports Med.*, vol. 11, no. 3, pp. 1–9, 2020, doi: 10.5812/asjsm.101670.

[17] M. A. Yalçın and M. Ulusoy, "Personal and Professional Attitudes of Architecture Students," *Procedia - Soc. Behav. Sci.*, vol. 174, pp. 1820–1828, 2015, doi: 10.1016/j.sbspro.2015.01.843.

[18] F. C. Lunenberg and B. Irby, *Writing a successful thesis or dissertation*, no. 1. Thousand Oaks, CA 9132: Corwin Press, Inc., 2008.

[19] M. S. B. Yusoff, "ABC of Content Validation and Content Validity Index Calculation," *Educ. Med. J.*, vol. 11, no. 2, pp. 49–54, 2019, doi: 10.21315/eimj2019.11.2.6.

[20] G. E. Gilbert and S. Prion, "Making Sense of Methods and Measurement: Lawshe's Content Validity Index," *Clin. Simul. Nurs.*, vol. 12, no. 12, pp. 530–531, 2016, doi: 10.1016/j.ecns.2016.08.002.

[21] A. Saputra, A. A. A. A. Kusumawardhani, S. D. Elvira, and T. Wiguna, "An item development, content validity, and feasibility study towards the Indonesian recovery scale for patients with schizophrenia," *Heliyon*, vol. 8, no. 11, p. e11826, 2022, doi: 10.1016/j.heliyon.2022.e11826.

[22] J. Hair and A. Alamer, "Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example," *Res. Methods Appl. Linguist.*, vol. 1, no. 3, p. 100027, 2022, doi: 10.1016/j.rmal.2022.100027.

[23] D. Navarro and D. Foxcroft, *Learning statistics with jamovi*. 2018.

[24] T. Septia, R. C. I. Prahmana, Pebrianto, and R. Wahyu, "Improving students spatial reasoning with course lab," *J. Math. Educ.*, vol. 9, no. 2, pp. 327–336, 2018, doi: 10.22342/jme.9.2.3462.327-336.

[25] Oregon Department of Education, "Importance of High-Quality Instructional Materials," no. June, 2022.

[26] J. Suh and J. Y. Cho, "Linking spatial ability, spatial strategies, and spatial creativity: A step to clarify the fuzzy relationship between spatial ability and creativity," *Think. Ski. Creat.*, vol. 35, no. December 2019, p. 100628, 2020, doi: 10.1016/j.tsc.2020.100628.

[27] M. Darwish, S. Kamel, and A. Assem, "Extended reality for enhancing spatial ability in architecture design education," *Ain Shams Eng. J.*, no. xxxx, p. 102104, 2022, doi: 10.1016/j.asej.2022.102104.

[28] E. Carmona-Medeiro, J. A. Antequera-Barroso, and J. M. C. noso Domingo, "Future Teachers' Perception Of The Usefulness Of Sketchup For Understanding The Space And Geometry Domain," *Heliyon*, vol. 7, no. 10, 2021, doi: 10.1016/j.heliyon.2021.e08206.

[29] I. Y. Alyoussef, "Acceptance of e-learning in higher education: The role of task-technology fit with the information systems success model," *Heliyon*, vol. 9, no. 3, p. e13751, 2023, doi: 10.1016/j.heliyon.2023.e13751.

[30] D. Fonseca, E. Redondo, F. Valls, and S. Villagrasa, "Technological adaptation of the student to the educational density of the course. A case study: 3D architectural visualization," *Comput. Human Behav.*, vol. 72, pp. 599–611, 2017, doi: 10.1016/j.chb.2016.05.048.

[31] M. Heo and N. Toomey, "Learning with multimedia:

The effects of gender, type of multimedia learning resources, and spatial ability," *Comput. Educ.*, vol. 146, p. 103747, 2020, doi: 10.1016/j.compedu.2019.103747.

[32] T. C. Huang and C. Y. Lin, "From 3D modeling to 3D printing: Development of a differentiated spatial ability teaching model," *Telemat. Informatics*, vol. 34, no. 2, pp. 604–613, 2017, doi: 10.1016/j.tele.2016.10.005.

[33] F. Malekian, A. R. F. Pour, and B. S. Pour, "Study the Effect of Supplemental Instructional Images on Students' Spatial Intelligence Degree," *Procedia - Soc. Behav. Sci.*, vol. 46, pp. 3301–3305, 2012, doi: 10.1016/j.sbspro.2012.06.055.

[34] R. Molina-Carmona, M. L. Pertegal-Felices, A. Jimeno-Morenilla, and H. Mora-Mora, "Chapter 11 Assessing the Impact of Virtual Reality on Engineering Students' Spatial Ability," *Futur. Innov. Technol. Educ. Policies Pract. Teach. Learn. Excell.*, pp. 171–185, 2018, doi: 10.1108/978-1-78756-555-520181013.

[35] A. Mitrache, "Spatial Sensibility in Architectural Education," *Procedia - Soc. Behav. Sci.*, vol. 93, pp. 544–548, 2013, doi: 10.1016/j.sbspro.2013.09.236.

[36] Nurjanah, B. Latif, R. Yuliardi, and M. Tamur, "Computer-assisted learning using the Cabri 3D for improving spatial ability and self- regulated learning," *Heliyon*, vol. 6, no. 11, p. e05536, 2020, doi: 10.1016/j.heliyon.2020.e05536.

[37] S. Y. Yoon and E. L. Mann, "Exploring the Spatial Ability of Undergraduate Students: Association With Gender, STEM Majors, and Gifted Program Membership," *Gift. Child Q.*, vol. 61, no. 4, pp. 313–327, 2017, doi: 10.1177/0016986217722614.

[38] V. Amitha and A. H. M. Vijayalaxmi, "Imparting social science curriculum through visual / spatial intelligence to foster active learning among the elementary school classroom," vol. 4, no. 1, pp. 240–244, 2018.