教學實踐研究計畫之學習成效分析與自變項依變項設計

鏘鏘｜林豪鏘

學習成效評量範例

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Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system

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This work focuses mainly on exploring the following questions:

(1) Are achievements in math and spatial ability related?
(2) Can AR-supported programs improve students' spatial ability?
(3) For students with various academic achievements, how effective is their learning after the experiment?
(4) What are students' perceptions of the system's usability?
(5) What are students' perceptions in terms of system task load?
(6) Is students' learning effectiveness related to the system's usability and task load?

4. Experimental results and analysis

4.1 *Validation of a correlation between spatial ability and math performance*

Question 1: Are achievements in math and spatial ability related?

Also, spatial ability was evaluated in terms of gender. Tests were conducted using Pearson corr . A situation in w on; and $r = 0$ im lue of the correl ute correlation c cor- relation coef the absolute correlation coefficient is higher than 0.8. Table 2 summarizes those results.

Table 2. Pearson's correlation.

		Mathematics performance
Math spatial perception	Pearson's correlation	.907**

Table 2 reveals that the spatial ability and mathematics scores are highly correlated and the spatial ability scores have a low negative correlation with gender. Restated, higher spatial ability scores imply higher mathematics scores. Therefore, spatial ability and gender are correlated with each other, yet only at a very low level. This finding resembles that described in PISA (2006).

- Regarding pre- and post-tests, **researchers prepared spatial ability test questionnaires** according to the course curriculum content, and referencing geometry courses by various publishers and **van Hiele's levels of geometric reasoning theory**.
- The test paper comprised 36 questions, including true–false, multiple choice, fill in the blank, try it out, and pictorial questions.
(是否，選擇、填空、試試看、圖片問題)
- Following completion of the tests, **two teachers proficient in mathematics were asked to evaluate the results.**
  - **The reliability was 0.85.**

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Table 1. Participant groups.

Group	Male	Female	Total
Control A: high-performing students	7	12	19
Experimental A: high-performing students	8	11	19
Control B: average-performing students	8	7	15
Experimental B: high-performing students	8	7	15
Experimental C: low-performing students	6	2	8
Total	37	39	76

4.2 *Verification of the effectiveness of learning*

Question 2: Can AR-supported programs improve students' spatial ability?

2a: Did the spatial ability performance of students in experimental group A improve?

2b: Did the spatial ability performance of students in experimental group B improve?

2c: Did the spatial ability performance of students in experimental group C improve?

This section examines whether the control and experimental groups differed in the spatial ability of students. The score of the experimental group A improved by 0.31, whereas the control group A improved by 0.63. The group difference can be calculated

Table 3. Descriptive statistics of high-performing and average-performing students.

	Mean	*S.*	σ	Group differences
Control A				
Pre-test	86.21	5.19	7.46	.12
Post-test	86.84	5.24		
Experimental A				
Pre-test	84.95	8.04	5.16	.04
Post-test	85.26	8.10		
Control B				
Pre-test	60.47	30.70	30.07	.31
Post-test	69.80	28.73		
Experimental B				
Pre-test	62.20	29.56	29.77	.36
Post-test	73.07	26.93		

- This difference revealed that the effective values were .31 and .37, indicating that the **two teaching methods** had **a minor positive effect**, and **significant differences**, as shown in Table 3.

- Table 4 summarizes the effective values of the three experimental groups.
- The effective values of groups with <u>high, average, and low academic achievements</u> were .04, .36, and .69, respectively, indicating <u>no effect</u>, a <u>small effect</u>, and an <u>average effect</u>, respectively.
- This finding suggests that <u>AR-assisted</u> teaching has a <u>favorable effect</u> on students with <u>low</u> academic achievements.

4.3 *Performance verification of students in each experimental group*

Question 3: For students with various academic achievements, how effective is their learning after the experiment?

An attempt was made to understand whether students' concepts changed by reviewing the response of each student. This section discusses significant progression, regression, or interesting phenomena. In the question regarding the unfolded diagram, correct responses from group A decreased, while those from group B and C increased. Namely, the students could construct 3D diagrams using parallel and vertical concepts in geometric shapes. Interviews with students in group A revealed no misconceptions. The decreased result of group A is thus assumed to be owing to the inability to carefully consider the answers. In the question regarding perpendicular face, group C increased significantly, while groups A and B did not significantly change. This indicates that for students with low academic achievements, using this system to teach the concept of perpendicularity is extremely beneficial. For questions – regarding counting of the vertex, sides and faces, groups B and C increased, group A changed only slightly. In the try it out section, which involves the concept of volume calculation and questions regarding the cutting and combining of unfolded diagrams, Groups B and C improved significantly. This finding reaffirms that with respect to experimental groups B and C, providing physical teaching materials is crucial to the instruction.

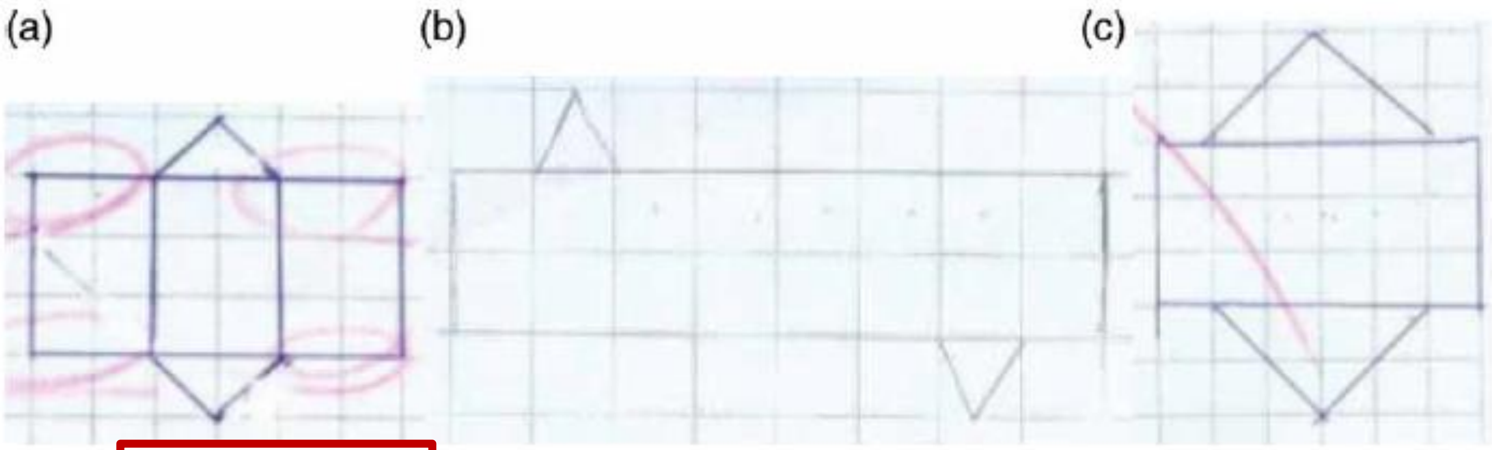

Figure 4. (a) Pre-test drawing from experimental group A and B (b) and (c) pre-test drawing from experimental group C.

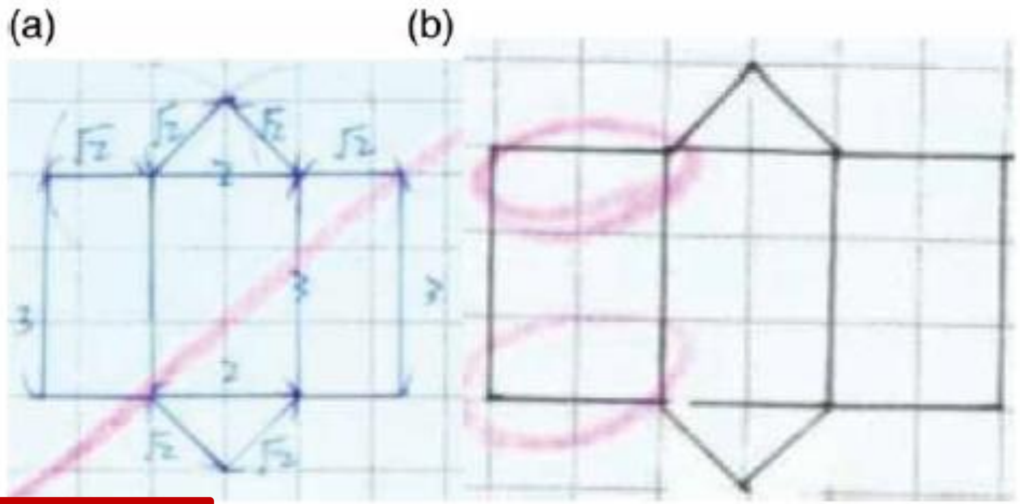

Figure 5. (a) Post-test drawing from experimental group A and B and (b) post-test drawing from experimental group C.

In the draw-a-diagram questions, following exposure to various teaching methods, students in the three groups performed better with respect to the shape-related concepts. Their performance regarding diagram-forming elements and the relationship between elements was more significant, particularly for groups B and C. Closely examining the responses revealed that most of the students in experimental groups B and C could draw the top and bottom surfaces and side faces before and after the test, as shown in Figure 4(a). Also, group C produced the drawings shown in Figure 4(b) and 4(c). According to those figures, prior to implementation of the teaching method, students had some misconceptions. Following the experiment, groups A and B modified their drawings, as shown in Figure 5 (a), indicating that they considered the relationship between graphical elements. Figure 5(b) illustrates drawings by group C students. Although groups with low academic achievements failed to produce completely accurate drawings, their drawings indicated that their level of geometric reasoning improved.

4.4 *System usability analysis and analysis of task load*

Question 4: What are students' perceptions of the system's usability?

The reliability of SUS obtained in this study was 0.879, with an overall average of 4, indicating that most users tilted toward the high end. SUS is a questionnaire that estimates users' subjective feelings and their degree of satisfaction with a system. Usability of the system is evaluated using the SUS score. The estimate scores range from 0 to 100. A higher score implies a more useful system and greater ease in which users can interact with it (Brooke, 1996; Lutes, Chang, & Baggili, 2006). After conversion into an SUS, the average score was 72.50. It indicated that student subjects were satisfied with respect to the usability of this learning system. As for the students' perceptions of the system

Question 5: What are students' perceptions in terms of system task load?

The reliability of NASA-TLX obtained in this study was 0.726, with an overall average value of 4.20, indicating a low feeling of task load experienced by most users. Variance analysis by ANOVA indicated that the three experimental groups did not significantly differ in terms of feelings toward students' perceptions in terms of system task load ($p = 0.096 > 0.5$).

4.5 *Verification of a correlation between the subjective perception and learning effectiveness of students*

Question 6: Is students' learning effectiveness related to the system's usability and task load?

6a: Is students' learning effectiveness related to system usability?

6b: Is students' learning effectiveness related to task load?

A correlation between the post-test scores of spatial ability and system usability was tested and verified using Pearson correlation analysis. Analysis results revealed a low degree of positive correlation between the post-test scores and system usability. The pre-test scores as control variables indicated a low level of negative correlation between the post-test scores and system usability. Restated, higher academic achievements of the students imply their lower perceived level of system usability. The pre-test scores were used as control variables, results showed that a low degree of correlation exists between the post-test scores and task load. Analysis results indicated a low degree of positive correlation between the post-test scores and task load.

4.6 *Results from observing participants during the focus group interviews*

Participant observation revealed that students displayed enthusiasm when instructed how to use the system. Students were also found to have a significant amount of curiosity and anticipation regarding the class. Additionally, the *post hoc* interviews and impressions of the instructor indicated that the students consider the system to be very interesting. Focus group interviews were conducted upon completion of the experiment. Open coding was performed based on grounded theory. During the encoding process, axial coding was conducted toward these directions, as shown in Table 5.

Focus group interviews were analyzed using qualitative analysis through the grounded theory (Strauss & Corbin, 1990), then the following four constructs were obtained: system usability, self-performance, willingness to operate, and expected effects. These constructs permit the quantitative analysis of Section 4.4. Qualitative and quantitative data analyses reveal the following:

(1) C1-System usability: The simple intuitive operation of AR can satisfy the test subjects' requirements of system usability.
(2) C2-Self-performance: The test subjects exhibit a positive attitude toward this system and are also influenced by self-esteem.

Table 5. Explanation of axial coding.

Coding number	Axial coding	Description	Open-style coding
C1	System usability	Reveals test subject's assessment of using the AR system	Learning time period Operating consideration Operating action Operating feel Guidance by others
C2	Self-performance	Self-evaluation by the test subject of their performance after using the system	Self-evaluate
C3	Willingness to operate	Willingness of test subjects to use the system if the opportunity arises to continue using the system	Willingness to self-operate Willingness to operate again AR acceptance level
C4	Expected effects	Test subjects' guessed the possible feelings of others and expressed possible expectations if the opportunity arises to using the system	Expected feeling Application in other disciplines System expectations

質性資料的編碼歸納-範例

收斂

歸納

主軸編碼代號	主軸編碼	說明	開放性編碼
C1	系統使用性	學習者對於系統之使用感受	使用感受
			系統設計
			系統易用性
			系統互動性
C2	介面設計	學習者對於系統介面設計之使用感受	使用感受
			介面使用性
			代理人
C3	課程設計	學習者對於使用系統學習課程之感受	課程內容
			教學策略
C4	使用意願	學習者繼續使用系統學習之意願	系統吸引力
			學習成就

訪談結果經由紮根理論（吳之儀、廖梅花，1988; Strauss.A, & Corbin.J, 1990）進行質性分析，得到四大構面如下：