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Multimedia Instruction Presented by Integrated Context to Enhance Understanding of Compass-and-Straightedge Construction

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ABSTRACT
This study examined the effectiveness of an integrated context approach to the instruction of basic compass-and-straightedge construction. The formulation of a perpendicular bisector of a segment was used as a knowledge module to guide students from the pre-attention level to the elaboration level of information processing. The students were expected to select and organize information in their working memory for integration with prior knowledge. The knowledge module was presented in a multimedia environment using a pre-training and rehearsal approach. In immediate and delayed test results, integrated context learning proved significantly more effective than the traditional context in preparing students to deal with retention problems and transfer problems, regardless of the students' prior knowledge. These findings demonstrate the effectiveness of integrated context in the instruction of compass-and-straightedge construction; however, the factors that actually facilitate learning have yet to be fully elucidated.
Keywords: cognitive load theory, compass-and-straightedge construction, integrated context, instructional message design

INTRODUCTION

The conceptual knowledge of compass-and-straightedge construction is demonstrated using an idealized ruler and compass through a series of procedures with the aim of enriching visualization skills and developing an appreciation of deductive proof (Sanders, 1998). Before learning complex constructions, students must grasp five basic compass-and-straightedge constructions: duplicating an angle, drawing an angle bisector, drawing a perpendicular

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State of the literature

- The cognitive load theory provide a number of guidelines for multimedia instructions. The guidelines mainly consider the display of information from its layout and content presentation.
- Learning performance depends largely on the complexity of learning materials, intrinsic cognitive load and the expertise of learners. Strategies using pre-training and segmentation of complex materials are generally used to improve learning.
- Information processing involves four levels that proceed from our sensory memory to working memory and long term memory. The higher levels require greater cognitive capacity and prior knowledge.

Contribution of this paper to the literature

- This paper outlines the design of an integrated context instruction that is able to help students to select, organize, and integrate the important information with their prior knowledge.
- Strategies are suggested in different phrases for information processing. It is argued that the communicability and connectivity are the key design to closely link the teaching materials and students' cognitive process.
- It is argued that an integrated context of conceptual and procedural for compass-and-straightedge construction is more effective than an isolated-interacting elements version, which is useful when operating appliances.

bisector of a line segment, and drawing a line perpendicular to a given line segment through a point outside or on the segment. Generally, geometric constructions are taught by presenting the steps of construction and then providing explanations of the operations. The underlying concepts involve the reflection symmetry of isosceles triangles (Perks & Prestage, 2006), rhombuses, or kites. Unfortunately, students tend to be confused by the steps associated with different constructions. Even when students are able to understand the related concepts, they are often unable to finish the constructions independently (Schoenfeld, 1985). The intricate interaction of conceptual and procedural knowledge in the learning of geometric constructions imposes a high cognitive load.

Cognitive load theory (Sweller, Ayres, & Kalyuga, 2011) provides a number of guidelines for the design of instructional methods. All of these principles are based on four assumptions (Sweller, Merrienboer, & Paas, 1998): (1) working memory is finite, (2) long-term memory is infinite, (3) knowledge and skills are stored in the long-term memory in the form of schemas, and (4) the automation of schema operations is an important process of schema construction. Due to the limited capacity of our working memory, reducing the extraneous cognitive load is fundamental to instructional design. When using multimedia to present instructional materials, both of the integrated format of mathematical diagrams and explanations (Sweller, 1994; Sweller, Chandler, Tierney, & Cooper, 1990), and presentations with synchronized narration (Leahy, Chandler, & Sweller, 2003; Yue, Bjork, & Bjork, 2013) are the strategies to improve learning. In the teaching of compass-and-straightedge construction, multimedia presentations can be used to demonstrate dynamic operations and enhance the accuracy of constructions. Nonetheless, students can still experience difficulty understanding the principles underlying the constructions.

The difficulty is due mainly to the relationship between the information being presented and the schemas held by students. According to the cognitive theory of multimedia learning (Mayer & Moreno, 2010), information received by sensory memory is organized in the working memory with prior knowledge. Thus, understanding depends on at least two simultaneous conditions: (a) Perceptual conditions: selection of important information by the sensory system, and (b) Cognitive conditions: activation of prior knowledge. The first condition can be attained by providing signals or cues (de Koning, Tabbers, Rikers, & Paas, 2007; Mautone & Mayer, 2001) to attract students' attention and thereby engage working memory. Learning performance can be enhanced by helping students to organize the information they are given and highlighting the essential relationships among the various representations (de Koning, Tabbers, Rikers, & Paas, 2009). The second condition is essential for learning structural knowledge such as mathematics.

According to cognitive load theory, knowledge and skills are stored in the form of schemas in our long-term memory. The knowledge can be understood and applied when it changes into schemas through systematic integration with existing schema. In the traditional instruction of compass-and-straightedge constructions, teachers demonstrate step-by-step constructions, followed by explanations. Unfortunately, students often have difficulty connecting "the how" and "the why" of the constructions. In other words, students are unable to integrate the prerequisite knowledge with the received information. They can construct the figure but the meaning of each step in construction often is not understood. In the meantime, there is high element interactivity (Sweller, 2010) produced by the procedural and conceptual knowledge concerning the constructions. Thus, a coherent context must be developed to activate schemas and decrease the number of interacting elements in order to guide integration.

This paper examines the effects of introducing an integrated context to the instruction of compass-and-straightedge constructions. We selected the perpendicular bisector of a line segment as the knowledge module for the instruction of other basic compass-and-straightedge constructions. The teaching materials were developed based on cognitive load theory, wherein extraneous cognitive load and cueing is reduced using highlighted information. We hypothesize that this approach to instruction could help students to select and organize information, and to guide them in integrating it with prior knowledge.

LITERATURE REVIEW

Instructional design: Multimedia learning

Multimedia instruction includes words as well as images (Mayer, 2009, 2014). Multimedia instruction might involve a diagram shown with corresponding printed text, an animation with narration on a computer, or a teacher narrating instructional pictures in a classroom. Researchers have shown that the appropriate use of multiple sensory cues in multimedia can enhance learning performance (Jiang & Benbasat, 2007; Moreno & Mayer, 2002; Schmidt-Weignad & Scheiter, 2011). According to dual code theory, two channels with limited capacity can be used to process information from different modalities. Presenting spoken narration with written text can create information overload (Mayer, 2009); therefore, the appearance and sequence of materials must take into account the specifics of each situation. For presentations that include only short phrases, the redundancy of concise spoken information can be used to guide the attention of learners (Mayer & Johnson, 2008). When written text is longer than one sentence, a sequential presentation of corresponding pictures and words tends to be more effective (Rummer, Schweppe, Fürstenberg, Scheiter, & Zindler, 2011).

For the layout of the instructional design, eliminating all non-essential information in multimedia messages were important for avoiding learners' attention, except for some authentic learning settings (Muller, Lee, & Sharma, 2008). For the design of the instructional content, highlighting important words and parts of the figure as well as placing text next to the part of the diagram were two usual ways that can enhance learning performance. Ginns (2006) reviewed the articles which were related to the spatial contiguity effect showed that physical integration of text and diagrammatic information was the effective ways of avoiding split attention and leading to better performance. However, the spatial contiguity was not restricted to text and diagram. Harter and Ku (2008) presented the problem text near to its corresponding illustrations of the two-step mathematics word problems. The students who use the spatially contiguous design showed a significant enhancement from pretest to posttest. Especially for lower-ability students, they exhibited a greater improvement by using the integrated design than the non-spatially contiguous condition. Another way to integrate information that came from different modalities can be showed by an animated descriptions or a virtual human gesture. The materials exhibited in Luzón and Letón (2015) were compared by a handwritten animation and static symbolic descriptions. In the handwritten animation version, a synchronic explanation was narrated for guiding students' learning. The perfect synchronization of the animation and its explanation showed the better effect than the static version both in recall and transfer tests. Furthermore, Craig, Twyford, Irigoyen and Zipp (2015) used an item-specific gesture by a virtual human who pointed at the mentioned items according to the instructional narration. Students who learned by the gesturing design outperformed those by the no-gesture condition in retention test. However, the significant difference did not indicate in transfer assessment.

Pointing gestures are visual cues that guide one's attention to important information. When dealing with more complex materials, a visual cue or signal, such as flashing symbols, arrows, or color changes, can help in learning by eliminating the need to search for corresponding information (Jeung, Chandler, & Sweller, 1997; Mautone & Mayer, 2001). Jamet (2014) used eye-tracking technology to record the total fixation times on relevant information. They showed that visual cues involving changes in the color of items when mentioned led to improvements in retention tasks but not in the transfer tasks. Scheiter and Eitel (2015) found that students who were given instructional messages by highlighting text-diagram correspondences had better text-diagram integration performance than those who were not. Similarly, no significant benefits were observed in transfer performance. The researchers theorized that this may be due to the fact that the signals were unrelated to prior knowledge. Clearly, a solid instructional design must take into account the presentation as well as the context of messages.

Instructional design: Reducing difficulties in learning materials

Learning performance depends largely on the complexity of learning materials, intrinsic cognitive load and the expertise of learners (Sweller et al., 2011). Pre-training and segmentation are two main strategies used to reduce the complexity of learning materials without changing the content of the presentation (Ayres, 2013). The expertise of learners is based on schemas stored in the long-term memory, which means that a pre-training design can help to reduce intrinsic cognitive load by developing key concepts as specific prior knowledge. Mayer, Mathias, and Wetzell (2002) used a pre-training sheet listing the names and characteristics of key components before presenting a narrated animation explaining the brake system of a car. The pre-training group demonstrated better learning performance in both retention and transfer tests.

Complex materials can also be broken down into essentials. Ayres (2006) separated the expansion of two polynomial expressions into four calculations, and found that students who used the segmented materials made fewer errors and rated the task easier. Spanjers, Wouters, van Gog, and van Merriënboer (2011) achieved similar results by segmenting animated examples of working out problems. Both studies observed an expertise reversal effect when students were given segmented learning materials. The segmenting of materials was a benefit only to students with poor prior knowledge, which means that this approach can be seen as isolating the learning elements in order to process the materials in many small steps. Pollock, Chandler, and Sweller (2002) developed the isolated-interacting elements learning approach for procedural and declarative knowledge, wherein the “what” and the “why” are both used to finish a complex task. They found that the performance of novice students who used this approach was superior to that of students who learned by integrating procedural and declarative knowledge. To summarize, the expertise of learners is a key point pertaining to the effectiveness of instructional methods. Furthermore, strategies that help learners to connect new information with prior knowledge are essential in multimedia instruction.

Instructional design: Information processing

Greenwald and Leavitt (1984) proposed four levels of audience involvement in an information processing model. First, learners recognize the features and significance of messages that came from sensory stimuli in the *pre-attention* level. According to feature integration theory (Treisman & Gelade, 1980), the preceding stage of processing sensory messages is influenced by recognizable elements, which can be selected in the parallel model.

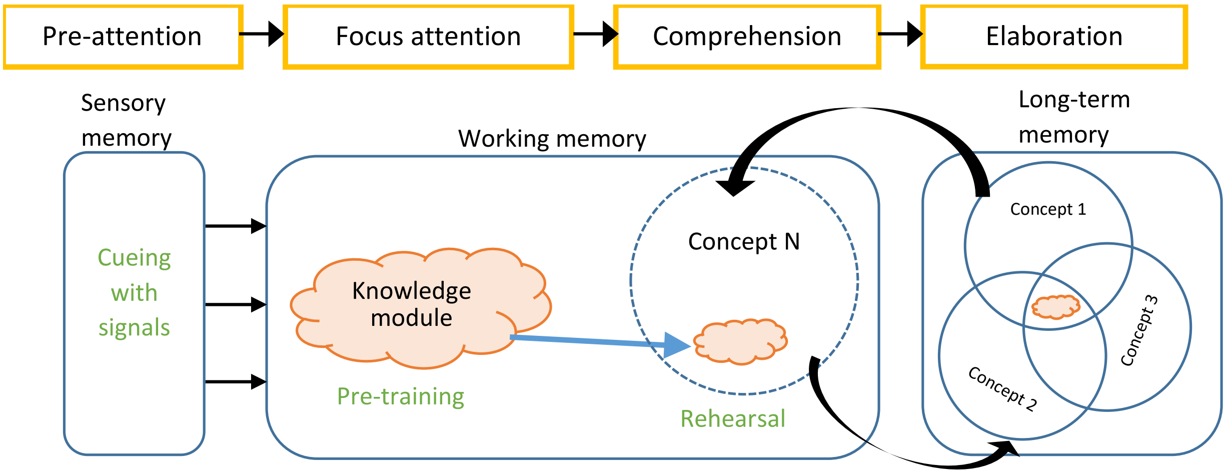

Figure 1. Instructional design and the four levels of learner involvement

For example, arrows can be used to indicate processes (Boucheix & Lowe, 2010), colors can be changed to point out main messages (de Koning, Tabbers, Rikers, & Paas, 2010; Jamet, 2014), and flashing symbols can be used to simplify learning (Hong, Thong, & Tam, 2004; Yantis & Jonides, 1990). Contextual cueing can be used to compensate for the limited capacity of our working memory (Chun, 2000) and thereby retain capacity for the follow-up learning.

Second, learners identify words and images related to learning at the *focused attention* level. This level generally involves basic information, such as the name, basic features, and uses of objects. Thus, a pre-training knowledge module can be added to enhance familiarity with key concepts. Third, learners in the *comprehension* level construct new knowledge by analyzing propositional relationships among learning objects and their functions. Fourth, rehearsal of the module helps students to form schemas in their long-term memory, whereupon learners at the *elaboration* level integrate and use the concepts they have learned. **Figure 1** presents the relationship between instructional design and the various levels of learner involvement.

Instructional design for information processing must exhibit two characteristics: communicability and connectivity. Communicability means that the instructional design should help learners to identify important information, such as visual cues. Connectivity refers to the integration of prerequisite knowledge and new elements using knowledge modules formulated through pre-training. When the concept of the knowledge module is developed, the rehearsal of this concept can be the support of the automation of schema operation. Thus, the knowledge module is integrated into different phrases of the teaching context. The communicability and connectivity are the important bridging between the teaching materials and the cognitive process of students.

METHODOLOGY

Participants and design

The participants in this study consisted of four classes of junior high school students (seventh-grade) in New Taipei City, Taiwan. The classes presented normal distribution in terms of student ability and prior knowledge. Two of the classes were randomly assigned to the experimental group (integrated context), and the other two classes formed the control group (traditional context). One hundred and twenty students participated in the study; i.e., 60 students in each group.

The study utilized a 2 (integrated context or traditional context) × 2 (high-achievement or low-achievement) between-subjects design. According to the average scores obtained by students on three mathematics tests administered during the previous semester, the two groups were divided into a high-achieving group (top 50%) and low-achieving group (bottom 50%). No significant differences were observed between the average scores in either the high-achieving group (t = 1.750; p > 0.05) or low-achieving group (t = -1.339; p > 0.05). Thus, the prior knowledge in the two groups could be considered equal.

Procedure

All participants were given a 45-min instructional session concerning the four basic compass-and-straightedge constructions. These sessions were taught by the same teacher. Before the lesson, participants were required to finish a pretest, including two fill-in-the-blank prior knowledge questions and four construction questions (10-min in total).

An instruction-oriented demonstration was presented using PowerPoint with AMA add-ins (Chen, Lee, & Hsu, 2015; Lee & Chen, 2015, 2016). AMA was deemed well-suited to the construction of geometric figures for instruction. It can be downloaded free of charge at http://ama.nctu.edu.tw/index.php. The slides showed to both groups were of the same instructional content but used different contexts (described below). The teacher conducted the class using PowerPoint with prompts and whole-class discussion. All participants took a 30-min posttest immediately after the instruction as well as the same posttest four weeks later.

Lesson materials

The principles of basic compass-and-straightedge construction are associated with the reflection symmetry of geometric figures, such as isosceles triangles, rhombuses, and kites. The participants were seventh-grade students; therefore, their knowledge of geometry was very limited. The students were taught to observe symmetry by folding geometric figures portrayed on the papers. The symmetry of perpendicular bisectors and isosceles triangles were taught to both groups, with the students in the traditional context groups also learning the properties of rhombuses and kites. This was taught as a pre-training activitiy prior to lessons on compass-and-straightedge construction.

The PowerPoint presentation shown to both groups was designed along the same instructional principles. Irrelevant words and pictures were first eliminated to reduce cognitive load. Textual descriptions were presented orally by the teacher; i.e., no written narration except key concepts appeared on the slides. This was done to reduce redundant cognitive load. Related visual information was presented in close spatial proximity, and image elements were displayed at the same time as the corresponding oral explanations. In other words, the elements were exhibited in detailed segmentation, thereby minimizing the number of elements that had to be added to each slide. Physical and temporal contiguity has been shown to reduce errors and save time. Fourth, the color of elements was changed to emphasize essential information. This emphasis also serves to minimize extraneous cognitive load.

An example instructional demonstration of angle bisector construction is presented in Appendix A. The materials used in the control group were presented within the traditional context. This consisted of two stages: construction and explanation. In the construction stage, the teacher explained and performed the construction procedures step-by-step. The teacher then explained the underlying principles. Students were encouraged to ask questions about each step in construction. The materials used in the experimental group were presented within an integrated context. The symmetry of the isosceles triangle was used to illustrate the construction of the perpendicular bisector of a line segment. The main property was explained to students as follows: "the median and the altitude from the same vertex as well as the angle bisector of the same vertex angle are the same line segment seen in the isosceles triangle". Thus, the construction of a perpendicular bisector in the experimental group was integrated as a knowledge module to guide the construction of other basic compass-and-straightedge concepts, including angle bisectors, and lines perpendicular to a given line segment through a point outside or on the segment. Instruction in the experimental group was divided into two parts: guidance and construction. In the guidance stage, the properties and construction process of a perpendicular bisector were first examined, and students were encouraged to connect the construction steps with prior knowledge. The construction of an angle bisector was guided by creating a key line segment, which was cut into two equal parts in the construction of a perpendicular bisector. After identifying the key line segment, each step was demonstrated according to the first construction stage. The perpendicular bisector module was used to overcome the effects of isolated elements and decrease interference among elements in order to reduce cognitive load.

Measures

A six-question pretest was used to assess students' prior knowledge of compass-and-straightedge constructions. The pretest questions address the concepts of isosceles triangles and the perpendicular bisector of a line segment as well as four basic compass-and-straightedge constructions.

The posttest comprised 6 retention questions and 7 transfer questions. The retention questions were the same as those used in the pretest, whereas the transfer test consisted of 7

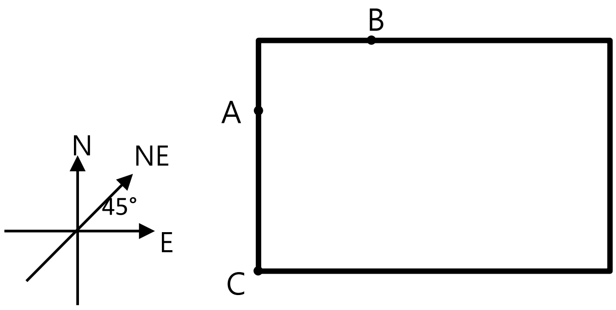

Figure 2. Figure used in one transfer question

construction questions. All the constructions require the application of knowledge from basic compass-and-straightedge constructions. Examples of transfer questions were as follows: "Given angle A of 120 degrees, construct a 30-degree angle with its vertex at A", "Given triangle ABC, construct the altitude to base BC from vertex A using only a compass and straightedge", "As shown in **Figure 2**, the government wants to construct a fountain in a park in the shape of a rectangle with three entrances: A, B, and C. The fountain is located northeast of entrance C equidistant to entrances A and B. Identify the exact location of the fountain using only a compass and straightedge".

Analysis

Students were awarded 5 points for each correct answer to pretest and retention questions. The construction questions were scored according to the correct steps drawn by students (partial grading), totalling 5 points for each question. Each correct answer to the transfer questions was awarded 6 points, except for the last question shown in **Figure 2**, which required that students to use two basic constructions for a total of 10 points. Cronbach's alpha for the pretest and posttest were 0.906 and 0.928, respectively.

RESULTS

We expected that students who were presented the compass-and-straightedge constructions within an integrated context would outperform the traditional context group on the posttest as well as the delayed posttest. We also posited that the ability of high-achieving students to activate their prior knowledge would enable them to outperform the low-achieving students. To evaluate these hypotheses, we conducted 2 (group: integrated context or traditional context) × 2 (achievement: high or low) × 2 (test: retention or transfer) analyses of variance (ANOVAs), with group and achievement conditions as between-participant factors and test scores as a within-participant factor. The means and standard deviations of all dependent measures are listed in **Table 1**. All statistical tests were conducted at a 0.05 level of significance. Effect sizes were calculated using Cohen's measure of effect size (indicated by partial η^2). According to Cohen (1988), η^2 values of 0.01, 0.06, and 0.14 correspond to small, medium, and large effect sizes, respectively.

Table 1. Mean scores and standard deviations in pretest, posttest, and delayed-posttest measures organized according to treatment and level of prior knowledge

		Integrated context group		Traditional context group	
		Low-Ach.	High-Ach.	Low-Ach.	High-Ach.
		n = 30	*n* = 30	*n* = 30	*n* = 30
Pretest (30 points)	*M*	5.37	8.93	5.23	8.10
	SD	(3.67)	(3.05)	(3.29)	(3.92)
Posttest (Total)	*M*	29.20	45.87	18.37	38.80
	SD	(15.98)	(15.44)	(10.80)	(15.53)
Retention (30 points)	*M*	16.97	23.93	11.07	21.80
	SD	(9.23)	(6.32)	(6.18)	(5.81)
Transfer (46 points)	*M*	12.23	21.93	7.30	17.00
	SD	(9.61)	(11.61)	(6.09)	(11.99)
Delayed posttest(Total)	*M*	23.43	36.97	12.03	29.83
	SD	(14.46)	(18.03)	(5.87)	(19.05)
Retention (30 points)	*M*	13.40	19.40	8.20	14.53
	SD	(6.93)	(7.00)	(4.00)	(7.18)
Transfer (46 points)	*M*	10.03	17.57	3.83	15.30
	SD	(8.97)	(12.71)	(3.01)	(12.46)

Treatment effects: Retention problems

Retention problems were included in all three tests. The mean scores are listed in **Table 1**. We employed a 2 (group: integrated context or traditional context) × 2 (achievement: high or low) × 3 (test: pretest, posttest or delayed posttest), design with repeated measures on the last factor, which revealed that the three-way interaction was not significant (p = .118). Nonetheless, significant interactions were observed between test and group, as well as test and achievement. To deal with interaction effects, we conducted separate univariate analyses of variance (ANOVAs). Simple effect tests revealed that high-achieving students in the traditional context achieved significantly higher scores (on all tests) than their low-achieving counterparts (pretest: $F(1, 116) = 25.377$, $p < 0.001$, $\eta^2 = .179$; posttest: $F(1, 116) = 47.705$, $p < 0.001$, $\eta^2 = .291$; delayed posttest: $F(1, 116) = 27.287$, $p < 0.001$, $\eta^2 = .193$). Students in the integrated context group significantly outperformed students in the traditional context group on the posttest ($F(1, 116) = 9.827$, $p < 0.01$, $\eta^2 = .078$) as well as delayed posttest ($F(1, 116) = 18.473$, $p < .001$, $\eta^2 = .137$). No significant differences were observed on the pretest scores between students with different levels of achievement in the integrated context group and traditional context group. This means that students with similar achievement were equal with regard to prerequisite knowledge pertaining to retention. As expected, students who underwent instruction within the integrated context significantly outperformed those who studied within the traditional context.

A significant main effect was observed between the different tests, $F(2, 232) = 212.674$, $p < 0.001$, as shown in **Figure 3**. A series of univariate tests was performed to further investigate this main effect. For the different context groups, we observed a significant increased in

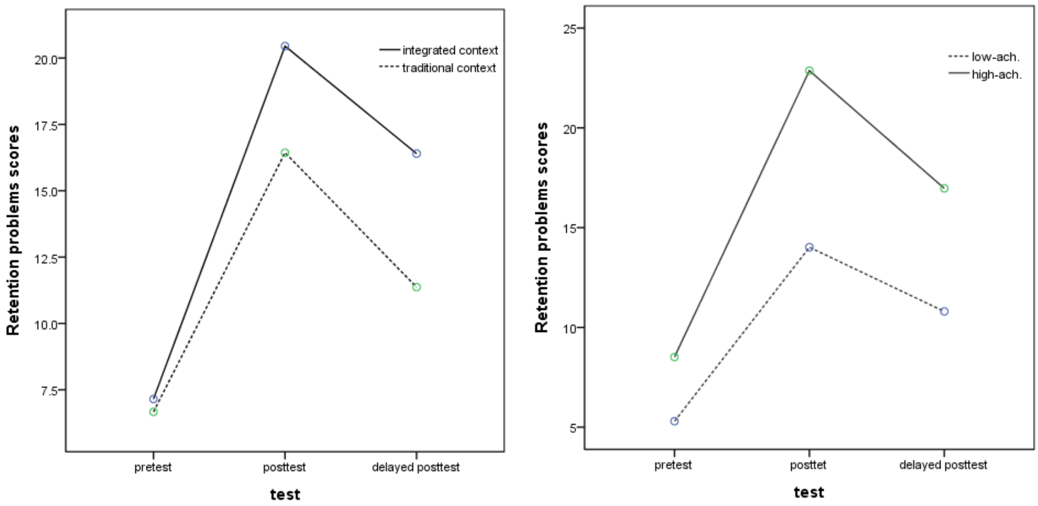

Figure 3. Mean retention scores across tests

retention scores from pretest to posttest; however, a significant decrease ($p < .001$) was found from posttest to delayed posttest ($p < .001$). For the different level achievers, a similar pattern was demonstrated from pretest to delayed posttest. These findings indicate that the integrated context had a slightly positive effect and that the high-achieving students benefitted the most. Furthermore, these effects were maintained over a period of four weeks, wherein delayed posttest scores in the integrated context group were similar to the posttest scores in the traditional context group.

Treatment effects: Transfer problems

Transfer problems were revealed in the posttest and delayed posttest. We conducted a 2 (group) × 2 (achievement) × 2 (test) design with repeated measures on the last factor to evaluate the scores of transfer problems. Analysis of these scores did not reveal significant interactions between test and context, $F(1,116) = 0.335$, $p > .05$, or between the test and achievement, $F(1,116) = 0.027$, $p > .05$. Furthermore, we observed significant effects on all the main effects (posttests: $F(1, 116) = 23.506$, $p < .001$, $\eta^2 = .168$; context: $F(1, 116) = 6.941$, $p = .010$, $\eta^2 = .056$; achievement: $F(1, 116) = 30.451$, $p < .001$, $\eta^2 = .208$). The performance of students when dealing with transfer problems was largely consistent with the results for retention problems. Students from the integrated context group outperformed those in the traditional context group. The positive effect was less pronounced after four weeks; delayed posttest scores from the integrated context group reduced similarly to the posttest scores from the traditional context group. In other words, most of the students cannot retain all the learning materials after four weeks; however, students in the integrated context group were better able to hold onto their knowledge and use it to solve transfer problems.

DISCUSSION

We used compass-and-straightedge constructions as an example of multimedia instruction within an integrated context to assist in the selection, organization, and integration of external information as a means of promoting knowledge activation and schema construction. These construction tasks possess conceptual and procedural knowledge that must be integrated for understanding. Formulating the integrated context design used in this study involved the creation of knowledge modules for the construction of the perpendicular bisector of a line segment as a scaffold concept. We employed cues to assist in the selection of information, a pre-training knowledge module for the organization of information, and a knowledge rehearsal module to facilitate integration with prior knowledge. Experiment results demonstrate that instruction within an integrated context is more effective than the traditional context. High-achieving students were shown to benefit from their prior knowledge, particularly with regard to knowledge integration.

Transfer involves using an existing schema with new knowledge to solve problems in new situations (Mayer & Wittrock, 1996). Mayer (1999) proposed numerous ways to promote problem-solving in a multimedia learning environment. Most of the principles concern perceptual design aimed at highlighting information by accessing visual and auditory channels. Nonetheless, even the best instructional design is unable to assist in transfer (Mayer & Johnson, 2008). New information must also be organized and integrated. Generally, the designs which can be the support for organized and integrated information are largely dependent on the prior knowledge of the students. Hence, this study provided a design using the integrated context for helping both displaying information and the cognitive process. This process exhibited superior transfer.

The traditional context in which explanations are given after the instruction of compass-and-straightedge constructions is of limited benefit. It enables students to imitate the steps of constructions; however, they cannot understand the reason for the operations. Separating procedural and conceptual knowledge can simplify matters; however, it is the interplay between the two types of knowledge that promotes an understanding of the underlying concepts. Our design was different from previous studies (Kester, Jirschner, & van Merriënboer, 2006; Pollock et al., 2002) in which an isolated-interacting elements instructional method was proposed. In that approach, the procedural steps were isolated from their declarative principles for creating electrical circuits. Separating these elements proved more effective than the interacting elements condition, which provided all the information to set up an electrical circuit. The operations of electrical circuits are different from the abstractions of geometric constructions. Electrical devices provide numerous indicators by which to illustrate the appropriate processes of creating a circuit, whereas geometric constructions provide only arcs and segments. Thus, the declarative principles can be separated from procedural knowledge, which can be clearly illustrated from the operational processes. However, the arcs and segments are not able to indicate the correctness about the process of geometric constructions. Thus, students must develop an understanding of the abstract mathematical concepts, which include both procedural and conceptual knowledge (Kyun & Lee, 2009).

In this study, the students in the integrated context group outperformed those in the traditional context group on the delayed posttest; however, they did not maintain their knowledge at the same level they demonstrated on the initial posttest. In other words, students must be given more opportunities to reflect on the knowledge in order to retain it. Specific strategies can be used to assist in the consolidation of schema related to geometric concepts. Providing example-problem pairs (van Gog, Kester, & Paas, 2011) and prompting students to explain the solutions they have worked out (Hodds, Alcock, & Inglis, 2014) can help to enhance the organization and integration of knowledge in the working memory. These methods encourage student to rethink what they have learned and consider how to apply it in new situations. Future studies might investigate the effects of additional exercises for practicing the concepts of compass-and-straightedge construction to improve performance on delayed posttests.

Two critical observations can be made regarding this study. First, we used the construction of the perpendicular bisector of a line segment to provide an integrated context. This concept was new for these students, and even though we employed a pre-training design, this training may have been insufficient to form a solid schema of the concept. Further pre-training may be needed to give students a foundation solid enough to assist in the construction of new knowledge. Thus, researchers could expand the knowledge module to include other concepts, such as rhombuses or kites, which may be more familiar to students and therefore more effective in transfer performance. Second, this study examined the effectiveness of integrated context instruction, which depends on the verbal guidance of the teacher. We used the same teacher in both groups; however, the verbal descriptions may have varied between presentations. A recorded narration (Luzón & Letón, 2015) could be used to reduce variations between presentations. Overall, an integrated context was shown to be highly effectively in guiding the instruction of basic compass-and-straightedge constructions. Nonetheless, the factors that actually benefit students have yet to be elucidated.

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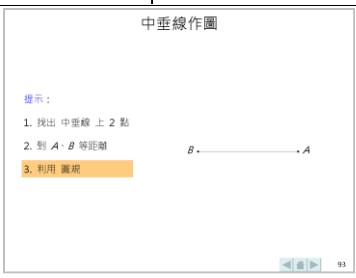
APPENDICES

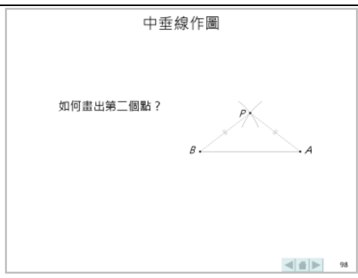
Appendix A

Screenshots of excerpted slides from the construction of the angle bisector

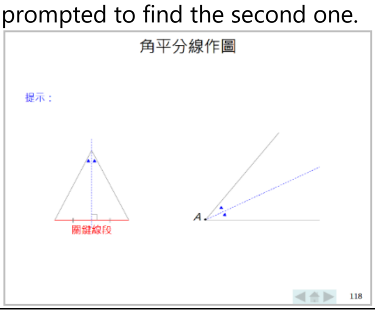
(1) In the integrated context group

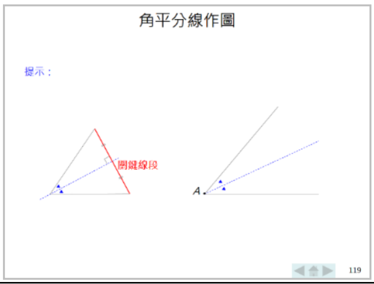
Stage	Slide & Description
Guidance	





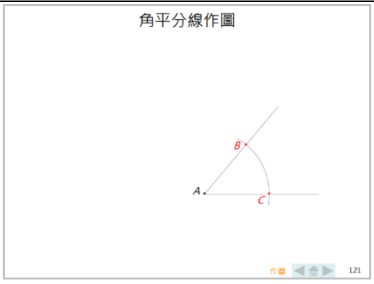
Some hints were shown to remind students of the construction of a perpendicular bisector of a segment. After the first point of the perpendicular bisector was drawn, students were prompted to find the second one.

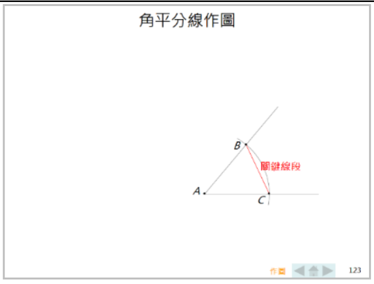




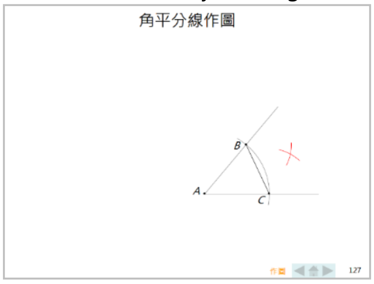
	Students were guided to identify the key line segment in the construction of a perpendicular bisector. After that, the diagram was rotated to match the orientation of the angle with its bisector. Students were prompted to find the construction procedure based on the key line segment.

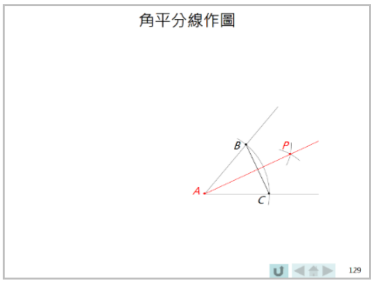
Construction





Construction followed the steps presented in the first stage.
1) Construct the key line segment.

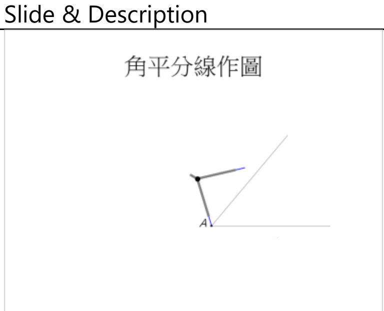


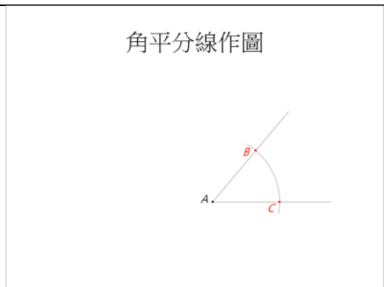


2) Find the second point of the perpendicular bisector by using your knowledge of the properties of the isosceles triangle.

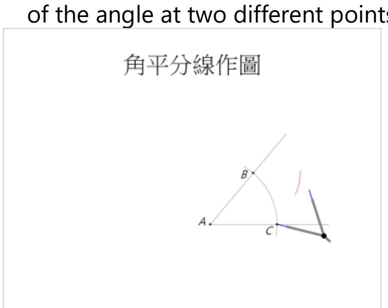
(2) In the traditional context group

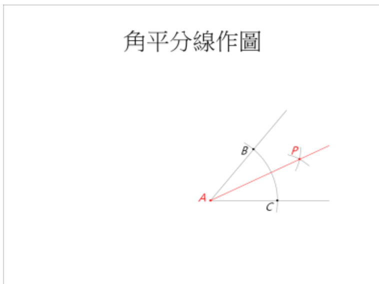
Stage	Slide & Description
Construction	





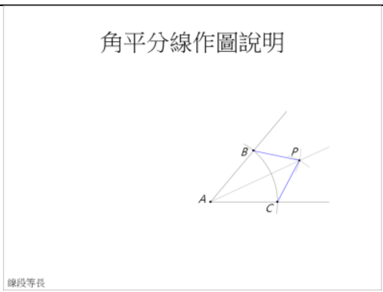
Steps of the construction:
1) Place the tip of the compass on vertex A of the angle and draw an arc which cuts each side of the angle at two different points *B*, and *C*.

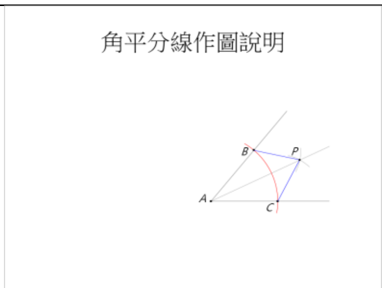




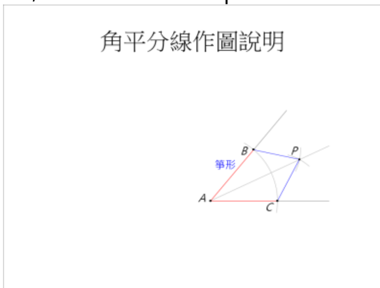
2) Place the tip of the compass on point *B* and *C*, respectively. Draw a second arc somewhere in the space contained in between the sides of the angle and a third arc which cuts the second arc to form a point *P*.

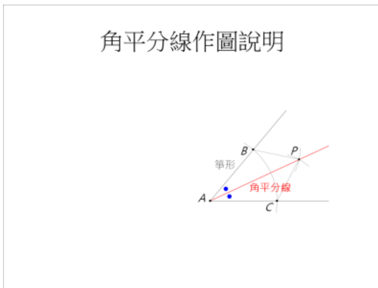
Explanation





Students were prompted and guided to focus on the length of the two adjacent sides *BP* and *CP*; *AB* and *AC* are equal.





Hence, the quadrilateral *ABPC* is a kite. Based on the symmetry of a kite, the symmetric line of the kite is also the angle bisector of the vertex angle *A*.