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### Computer-based learning of geometry from integrated and split attention worked examples: the power of self-management

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# Computer-based learning of geometry from integrated and split attention worked examples: the power of self-management

## Abstract

This research investigated the viability of learning by self-managing split-attention worked examples as an alternative to learning by studying instructor-managed integrated worked examples. Secondary school students learning properties of angles on parallel lines were taught to integrate spatially separated text and diagrammatic information by using online tools to physically move text to associated parts of a diagram. The moving of text aimed to reduce learners' need to search between text and diagram, freeing cognitive resources for learning and affording learners' control of their learning materials. The main hypotheses that learners who self-manage split-attention worked examples would perform better on test items than learners who study split-attention worked examples, and perform as well as learners who study instructor-managed integrated worked examples were confirmed. Theoretical and practical implications of the results are discussed.

## Keywords

worked, attention, split, integrated, learning, self, management, power, computer, examples, geometry

## Disciplines

Education | Social and Behavioral Sciences

## Publication Details

Tindall-Ford, S., Agostinho, S., Bokosmaty, S., Paas, F. & Chandler, P. (2015). Computer-based learning of geometry from integrated and split attention worked examples: the power of self-management. *Educational Technology and Society*, 18 (4), 89-99.

## Computer-Based Learning of Geometry from Integrated and Split-Attention Worked Examples: The Power of Self-Management

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### ABSTRACT

This research investigated the viability of learning by self-managing split-attention worked examples as an alternative to learning by studying instructor-managed integrated worked examples. Secondary school students learning properties of angles on parallel lines were taught to integrate spatially separated text and diagrammatic information by using online tools to physically move text to associated parts of a diagram. The moving of text aimed to reduce learners' need to search between text and diagram, freeing cognitive resources for learning and affording learners' control of their learning materials. The main hypotheses that learners who self-manage split-attention worked examples would perform better on test items than learners who study split-attention worked examples, and perform as well as learners who study instructor-managed integrated worked examples were confirmed. Theoretical and practical implications of the results are discussed.

### Keywords

Cognitive load theory, Split-attention, Self-management of split-attention, Worked examples

### Introduction

Today's online learning environment provides learners with access to information of variable quality, both academically and structurally. Learners need to be able to assess the academic quality of information, recognize poorly constructed materials, and reorganize information to support their learning. This paper explores the efficacy of teaching learners to reorganize information by manually integrating related text within a diagram to reduce search and support their understanding of mathematical concepts, thus decreasing the load on working memory and enhancing learning. The research was informed by Cognitive Load Theory (CLT) (Paas, Renkl, & Sweller, 2003; Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011), which posits that effective instructional design should take into account human cognitive architecture, specifically focusing on effective use of limited working memory resources (Ayres & Paas, 2008). CLT instructional designed materials aim to remove processing of superfluous information (extraneous cognitive load), manage the difficulty of the information to be learnt (intrinsic cognitive load), while optimizing the learners' processing capacity for what is relevant to learning (germane cognitive load) (Sweller, 2010). Traditionally, CLT research has focused on the instructor/teacher-designed learning materials that fulfill the above. Some of the best-studied instructional approaches include the worked example effect (Atkinson, Derry, Renkl, & Wortham, 2000; Sweller & Cooper, 1985; for an overview see Sweller, Ayres, & Kalyuga, 2011). This effect occurs when learning is enhanced by studying worked examples which are stepped-out solutions rather than being presented with the equivalent problem with no stepped-out solution. Another instructional principle is the split-attention effect, which was found when studying a specific type of worked example, consisting of mutually dependent but spatially separated text and diagram, and solving the equivalent problems were equally ineffective for learning (Sweller, Chandler, Tierney, & Cooper, 1990). The split-attention effect is defined as the lowering in learning performance caused by presenting mutually dependent, but spatially separated sources of information (e.g., text and diagram) in the visual modality, requiring the learner to invest working memory resources to integrate the dispersed information. This study investigated a new perspective on the split-attention effect, in which learners are taught to self-manage sources of split-attention in worked examples.

The split-attention effect occurs when a learner is forced to search and mentally integrate related information that is incomprehensible in isolation due the design of the instructions (Ayres & Sweller 2005). It is the searching and mental integration undertaken by the learner that places an extraneous load on limited working memory resources and inhibits learning (Chandler & Sweller, 1991). Aligned with the split-attention effect are the spatial and temporal contiguity effects (Mayer, 1997; Mayer & Moreno, 2003; Moreno & Mayer, 1999). Both effects focus on the importance of ensuring that related information be close in proximity in regard to space (spatial contiguity effect) or

time (temporal contiguity effect). Ginns' (2006) meta-analysis on the importance of reducing learners' split-attention showed that integrated instructions led to more efficient and effective learning compared to instructions presented in a split-attention format. An example of split-source materials may include a diagram with related written text presented above, below or to the side. Under split source instructional conditions the learner is forced to mentally hold and integrate in working memory the related diagram and text in order to process and understand the instructions (see Figure 1). It is the division of cognitive resources that poses an extra load on limited working memory, which impedes learning. This can be mitigated by integrating related information (see Figure 2). It is argued that, as learners are no longer required to mentally search and match text with diagram, extraneous load is reduced and cognitive resources are freed for learning. The benefits of integrated instructions as an alternative to split source materials has been demonstrated across a range of learning domains including mathematics (e.g., Tarmizi & Sweller, 1988), physics (e.g., Ward & Sweller, 1990), engineering (e.g., Mayer, 1989) and second language learning (e.g., Chung, 2008). Traditionally the research has relied on an expert instructor designing the integrated instructions. The novelty of the current research is the investigation of the efficacy of teaching learners to meaningfully integrate text with a diagram to reduce search and support learning.

Self-management as an alternative to instructor management of cognitive load is a new development in CLT research (Agostinho, Tindall-Ford, & Bokosmaty, 2014; Agostinho, Tindall-Ford, & Roodenrys, 2013; Roodenrys, Agostinho, Roodenrys, & Chandler, 2012). Self-management in this current experiment required the learner to move textual information to parts of the diagram which the learner understands are related, the aim being to reduce learners' need to search and freeing cognitive resources for learning. Despite learners in the self-managed condition being required to undertake an additional task to integrate text and diagram, this task may serve to not only reduce searching between related sources of information but also focus learners attention on the to be learnt material thus increasing germane load (see also Paas & Van Gog, 2006; Paas & Van Merriënboer, 1994). Roodenrys et al. (2012) investigated the effectiveness of teaching self-management skills to tertiary students. Two experiments in the domain of educational psychology showed the superiority of integrated instructions compared to traditional split-attention materials. The research provided some evidence to suggest that self-management may be an alternative to instructor managed integrated instruction. An interesting finding was that teaching the strategy of self-management was transferable, with the self-management group significantly outperforming both integrated and split-attention groups on test items in a different learning domain. Follow-up research on self-management in an online environment with tertiary students was undertaken by Agostinho et al. (2013). The research, conducted with pre-service teachers in an educational technology subject, utilized both qualitative and quantitative measures to investigate the efficacy of self-managing split-attention online. Quantitative results demonstrated that integrated instructions were superior to split source and self-management instructions, confirming a split-attention effect. Results showed that although there was not a significant difference in favor of the self-management group, this group did perform better on all test items compared to the split-attention group. This result was despite the fact that the self-management group was required to undertake the additional task of moving text to integrate with the diagram during the learning phase. Qualitative results, which were obtained by verbal protocols, suggested that explicit instruction and training are required for learners to understand how to successfully integrate text with diagram to self-manage split-attention. Thus, the preliminary research conducted to teach students to manage split-attention themselves indicates that learners who are guided on how to physically manipulate either print or computer based instructional materials with evident split-attention perform as well, and on some test items better, than learners learning from split-source instructions.

Another potential advantage for enabling learners to self-manage split-attention materials is that it provides a form of learner control which can lead to a higher level of learner engagement (Orvis, Fisher, & Wasserman, 2009). This is a form of germane cognitive load, which potentially enhances learner understanding (Hasler, Kersten, & Sweller, 2007). It is speculated that self-management requires learners to actively engage with the "to be learned content," which may lead to enhanced processing and schema construction. However a meta-analysis on the positive benefits of learner control in computer-based training indicated the benefits to learning are relatively small (Kraiger & Jerden, 2007). Granger and Levine (2010) suggested for novice learners when first learning complex information in a computer based learning environment, it is important that the learner has only minimal control and decision-making. Research indicates that when information to be learnt is high in complexity (high element interactivity) with a corresponding high working memory load it is essential not to further burden novice learners' working memory with additional activities or decision making that are not aligned with learning (e.g., Bokosmaty, Sweller, & Kalyuga, 2014). To optimize self-management of the split-attention effect in this research, novice learners were given limited choices and decisions to make when manually integrating related text within a diagram. Furthermore, specific

guidance and training on the reasons why and how to self-manage the split-attention effect was integral to the experimental design.

The current study investigated the effects on secondary students' geometry learning of a self-management strategy for cognitive load by physically manipulating digital instructional materials with evident split-attention. Similar to the previous research on self-management of cognitive load (Agostinho et al., 2013; Roodenrys et al., 2012), the effectiveness was determined by comparing the self-management condition to an instructor-managed condition with physically integrated instructional materials and no split-attention, and to a traditional split-attention condition.

Firstly, it was hypothesized that participants studying split-attention worked examples, who are provided with guidance on how to self-manage split-attention, would outperform participants studying split-attention worked examples on a transfer test (Hypothesis 1). Secondly, it was hypothesized that participants studying instructor-managed integrated worked examples (that is, with no evident split-attention) would outperform participants studying split-attention worked examples on a transfer test, thereby replicating the split-attention effect (Hypothesis 2). Thirdly, it was hypothesized that participants studying split-attention worked examples and provided guidance on how to self-manage split-attention would perform equivalent to participants studying instructor-managed integrated worked examples on a transfer test (Hypothesis 3). Fourthly, with regard to cognitive load during learning, it was hypothesized that participants studying split-attention worked examples and participants self-managing split-attention worked examples would have higher cognitive load ratings for studying instructions than participants studying instructor integrated worked examples (Hypothesis 4), due to higher extraneous load in the split-attention condition and higher germane load in the self-management condition. Fifthly, with regard to cognitive load during the transfer test, it was hypothesized that participants in the split-attention condition would report higher cognitive load than participants in the instructor-managed and self-managed conditions (Hypothesis 5), because of the higher quality of schemata constructed in the latter two conditions during learning.

## Method

### Participants and design

Participants were 48 female Year 7 students (between 12 and 13 years of age) from a New South Wales secondary school. The students and their parents/carers consented to participate in the study. All students had participated in an introductory lesson (designed and delivered by one of the researchers) to revise concepts such as parallel lines and introduce the concept of alternate and co-interior angles on parallel lines. This lesson however, did not explain how to calculate corresponding and alternate angles on parallel lines, as this was the focus for the experiment. The experiment was conducted across eight school days over a period of two school weeks during the third of four 10-week school terms. Participants were randomly assigned to one of three conditions:

- Split-attention
- Integrated
- Self-managed

### Materials and procedure

The instructional material was based on New South Wales Board of Studies Mathematics K-10 Stage 4 (Years 7 and 8) syllabus outcomes (*Stage 4, Measurement and Geometry: Angle Relationships in Board of Studies, 2012*). The topic of properties of angles on parallel lines was selected because students were scheduled to study the subject matter in the subsequent school term, thus the experiment served as an introduction to these mathematical concepts.

Prior to the commencement of the experiment all students in the four mathematics classes received a 45-minute lesson taught by one of the researchers. In this lesson the researcher revised geometry concepts such as parallel lines, transversal lines and angles on straight lines adding up to  $180^\circ$ . These concepts had been introduced to the students earlier in the year (in the first school term) and thus, this part of the lesson served as revision. The second part of the lesson introduced the two new topics: alternate and co-interior angles on parallel lines. Participants completed a worksheet during the lesson to reinforce the content presented in the lesson. Students participated in the experiment one week after participating in this introductory lesson. The experiment took fifty minutes and was undertaken in

groups of two to three participants from the same instructional condition with one researcher in a large tutorial room. Each participant worked independently at a designated laptop computer and was unable to view other participant's computers or work. The instructional materials were developed using an interactive whiteboard software application called SMART Notebook. This software application (similar to Powerpoint) enables text and shapes to be moved on the screen as objects. Three SMART Notebook files were developed (one for each condition) each consisting of 10 slides. The instructional materials were formatted as follows.

*Split-attention:* Instructional materials comprised of worked examples presenting parallel lines with a number of angles indicated on the top half of the screen followed underneath by a series of textual statements explaining the relationship between and the calculation of the angles (see Figure 1). The text and diagram were “locked” and were not movable.

*Integrated:* Instructional materials included worked examples showing the same parallel lines, angle and textual statements, as in split-attention condition, however the textual information was integrated on the diagram to reduce split-attention (see Figure 2).

*Self-managed:* Instructional materials included worked examples showing the same parallel lines, angle and textual statements, as in split-attention condition, however the text statements were movable (see Figure 3).

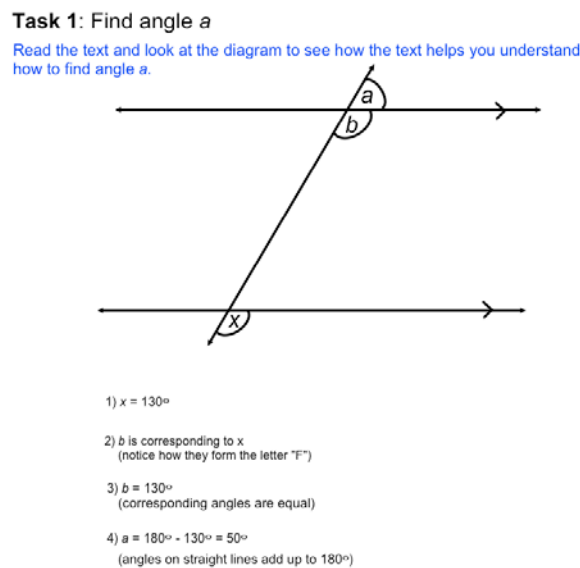


Figure 1. Example of a split-attention worked example (split-attention condition)

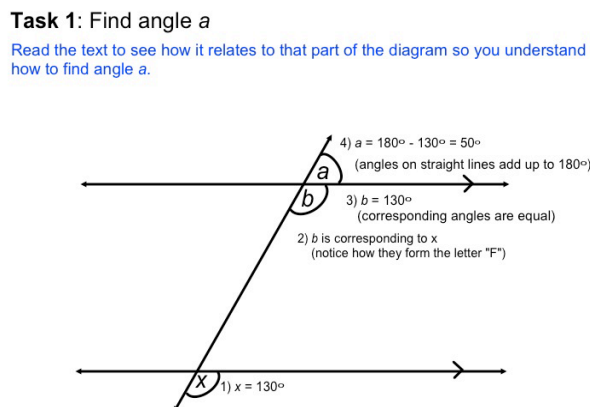


Figure 2. Example of an integrated worked example (integrated condition)

**Task 1: Find angle a**

Read and move each text box to the relevant place on the diagram that helps you understand how to find angle a.

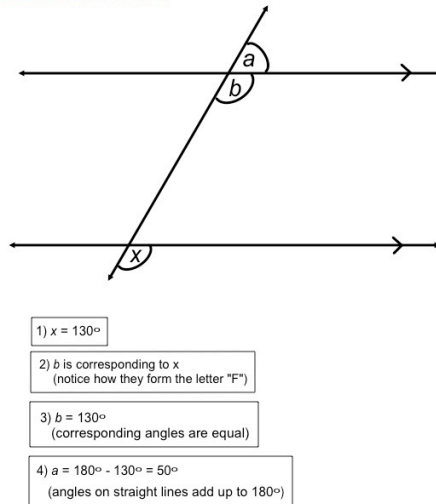


Figure 3. Example of a self-management worked example (self-managed condition)

The experiment comprised four phases, which are described below.

*Phase 1: Revision of concepts taught in lesson (5 minutes)*

Participants worked through four SMART Notebook slides to revise the concepts taught in the previous week's mathematics lesson on parallel lines and angles. All participants, irrespective of their allocated condition, worked through the same four SMART Notebook slides. The first SMART Notebook slide provided information on parallel and transversal lines, the second slide showed how two angles on a straight line add up to  $180^\circ$ , the third slide showed the different positions of alternate angles on parallel lines and how alternate angles are equal. The final slide showed the different positions of co-interior angles on parallel lines and how they add up to  $180^\circ$ .

*Phase 2: Training of instructional condition: (10 minutes)*

The training phase comprised two Notebook files where participants were presented with two worked examples based on the instructional condition to which they were allocated. The worked examples were focused on how to calculate angles on a straight line when presented with 2 parallel lines and 1 transversal line. Each worked example provided a two-step solution on how to calculate an angle on a straight line. The two-step solution was presented as 2 text statements. For the split-attention and self-managed conditions the two text statements were presented underneath the diagram. In the integrated condition the two text statements were positioned in the relevant parts of the diagram. Participants were provided with verbal instructions from the researcher on how they were to study the worked example based on the instructional condition to which they were allocated. Based on the results from the pilot study, the verbal instructions for each condition were simplified to provide clear explicit instructions for the participants to practice. The verbal instructions provided were as follows:

**Split-attention condition:**

To understand how to calculate angles  $a$  and  $b$ , please do the following:

- (1) Look at the diagram
- (2) Read each text statement
- (3) Re-read each text statement one at a time and search the diagram to see how the statement relates to the diagram and explains how to calculate the angle.
- (4) Review the diagram and text statements to understand how each angle is calculated.

Integrated condition:

To understand how to calculate angles a and b, please do the following:

- (1) Look at the diagram.
- (2) Read each text statement next to the angle.
- (3) Re-read each text statement, look at the diagram to understand how each angle is calculated.

Self-managed condition:

To understand how to calculate angles a and b, please do the following:

- (1) Look at the diagram
- (2) Read each text statement
- (3) Re-read each text statement one at a time and move the text to a part of the diagram so it helps you understand how the angle is calculated.
- (4) Review the diagram and text statements to understand how each angle is calculated.

Note how the moving of the text helps you to reduce your need to search between diagram and text.

After the two examples the researcher re-iterated to the participants that they were to use this learning technique in the four worked examples (Phase 3) they were about to learn.

Following the training for the instructional condition, an explanation of how to complete a subjective mental effort rating scale was provided. An established nine point Likert mental effort rating scale (Paas, 1992) was introduced. Participants were explained the concept of mental effort and provided with three examples to show the different extremities of the scale. Participants were instructed that they would be required to indicate the mental effort used on two occasions during the experiment, firstly after they had learnt the information and secondly after the completion of answering questions.

#### *Phase 3: Learning to solve for angles on parallel lines (6 minutes)*

After completing Phase 1 and Phase 2, participants worked through four worked examples, each worked example provided a four-step solution on how to solve alternate angle problems (worked examples 1 and 2) and co-interior angle problems (worked examples 3 and 4). Each worked example was presented on one Notebook slide (Figures 1-3 illustrate the first worked example). Participants were given 90 seconds on each slide and were then asked to move to the next slide. The researcher reiterated to the group of three students at each slide that they must use the learning approach they learnt in the training phase. The first and second worked examples showed how to solve for two angles on parallel lines using the rules; angles on a straight line add up to  $180^\circ$  and alternate angles are equal. The third and fourth worked examples required students to understand how to solve for two angles on a parallel line using the rules; angles on a straight line add up to  $180^\circ$  and co-interior angles add up to  $180^\circ$ . At the completion of the four slides participants were asked to circle the mental effort required to understand the information.

Following the learning phase, the researcher saved the Notebook files for all participants in the self-managed condition. Each file was saved and analyzed post-hoc to check that participants had implemented the guidance provided, i.e., compliance of the self-management condition. Participants who did not move text to some part of the diagram in an attempt to self-manage split-attention were not included in the final data analysis. Review of all Notebook artifacts showed one student failed to move text in the self-managed condition.

#### *Phase 4: Transfer test (11 minutes)*

Participants completed a paper-based test that included five parallel line angle problems with each problem presented on one page. Prior to starting the test, the participants were provided a worked example of how to answer test problems, where the researcher explained the need to provide the angle and a short justification on the reasons why the angle must be stated in degrees. Participants were required to complete questions in order, were not allowed to go back to a previous question, and had eleven minutes to complete all questions.

The test was designed to assess students' ability to solve problems applying the three main rules learnt:



- (1) Angles on a straight line add up to  $180^\circ$ .
- (2) Identifying the position of alternate angles on parallel lines and applying the rule that alternate angles are equal.
- (3) Identifying the position of co-interior angles on parallel lines and applying the rule that co-interior angles add up to  $180^\circ$ .

There were five test items, all of which required the students to transfer the acquired knowledge to a certain extent. The first two test items were similar to problems studied during the learning phase, but had different values. Participants needed to apply two rules to solve for two angles. The first item focused on solving for an alternate angle. The second item focused on solving for a co-interior angle. The last three test items were different to problems studied during the learning phase, and therefore required further transfer of the knowledge acquired during the learning phase. The third test item focused on solving for a co-interior angle but was presented differently to that studied during the learning phase in that the transversal line was presented in the opposite direction. The fourth test item required participants to solve for both alternate and co-interior angles and the last test item required solving for both alternate and co-interior angles on a problem that was both superficially and structurally different from what participants were exposed to in the learning phase (i.e., parallel lines were rotated  $45^\circ$ ).

Each problem was scored using a marking system developed by a mathematics teacher (one of the researchers – who also gave the introductory lesson). One mark was awarded for the correct angle e.g.,  $r = 50^\circ$  and one mark for the text written rationale, e.g., “angle  $r$  alternate to angle  $m$ , alternate angles are equal.” The first two test items comprised solving 2 angles; each were marked out of 4. The third test item comprised solving 2 angles and was marked out of 4. The fourth test item comprised solving 3 angles, and was marked out of six. The last test item included 4 angles to solve, and was marked out of eight. The maximum test score was 26.

## Results

For all analyses a significance level of .05 was used. Cohen’s  $d$  was calculated as a measure of effect size, with values of .10, .30, and .50 characterizing small, medium, and large effect sizes, respectively (Cohen, 1988). One-way analyses of variance (ANOVAs) were conducted on transfer test performance scores and ratings of mental effort invested in the learning phase, and in the test phase. Means and standard deviations for transfer test performance and mental effort ratings in the learning and test phase are presented in Table 1.

*Table 1. Means and (SD) for transfer test performance and mental effort during the learning and test phase*

Condition	Performance (Maximum score 26)	Mental effort ratings (Range: 1 – 9)	
	Transfer test	Learning phase	Test phase
Split-attention ( $N = 15$ )	14.33 (6.40)	3.87 (1.60)	5.20 (1.74)
Integrated ( $N = 17$ )	20.34 (5.73)	3.12 (1.50)	4.41 (1.91)
Self-managed ( $N = 16$ )	19.44 (4.97)	3.50 (1.71)	4.81 (1.83)

Results from the one-way ANOVA for transfer-test performance indicated a significant main effect between the three conditions,  $F(2, 45) = 4.887$ ,  $MSe = 32.630$ ,  $p = .012$ . Post-hoc comparisons using the Tukey HSD test showed that the mean transfer test score of the self-managed condition was significantly higher than the mean score of the split-attention condition,  $p = .043$ ,  $d = 0.89$ , indicating a large effect size (Cohen, 1988). Hypothesis 1 was thus confirmed. In addition, the mean transfer score of the integrated condition was significantly higher than the mean score of the split-attention condition,  $p = .015$ ,  $d = 0.97$ , indicating a large effect size. The results replicate a split-attention effect thus confirming Hypothesis 2. There was no significant difference between the integrated and self-managed conditions,  $p = .915$  and a low effect size was obtained,  $d = 0.15$ . This suggests that the self-managed condition performed equivalent to the integrated condition thus confirming Hypothesis 3.

Results from the one-way ANOVA for mental effort invested in the learning phase indicated no significant difference between the three conditions,  $F(2, 45) = 0.873$ ,  $MSe = 2.567$ ,  $p = .425$ . Thus Hypothesis 4 was not confirmed. However, a medium effect size was obtained between the integrated and split-attention conditions,  $d = 0.48$ ; whilst a low effect size was obtained between the self-managed and split-attention conditions,  $d = 0.22$ , and between the integrated and self-managed conditions,  $d = 0.24$ .

Results from the one-way ANOVA for mental effort invested in the test phase indicated no significant difference between the three conditions,  $F(2, 45) = 0.740$ ,  $MSe = 3.355$ ,  $p = .483$ . Thus Hypothesis 5 was not confirmed. A medium effect size was obtained between the integrated and split-attention conditions,  $d = 0.43$ ; a low effect size was obtained between the self-managed and split-attention conditions,  $d = 0.21$ , and between the integrated and self-managed conditions,  $d = 0.21$ .

## Discussion

This study investigated the potential of students' self-management of split-attention in worked examples for geometry learning in digital learning environment. The self-management strategy was compared to a condition in which students could learn from instructor-managed integrated worked examples, and to a condition in which students had to learn for split-attention worked examples. The results on transfer test performance confirmed Hypothesis 1, indicating that students who are provided the opportunity to physically integrate information sources in split-attention worked examples show better learning than students who study split-attention worked examples without the opportunity. In line with Hypothesis 2, we replicated the split-attention effect, indicating that students learn more from studying integrated worked examples than from studying split-attention worked examples. Hypothesis 3 was confirmed as the test performance results showed that there was no significant difference in performance between the integrated and self-managed conditions. Hypotheses 4 and 5 could not be confirmed, because the analyses revealed no significant differences between the instructional conditions for cognitive load during learning and during the test.

In the previous studies on the effects of self-management of split-attention on learning by Agostinho et al. (2013) and Roodenrys et al. (2012) the results revealed that learners' adopting a self-management strategy to reduce split-attention performed better on test items compared to learners learning from split-attention instructions but learners did not perform as well as those learners provided with optimally designed instructions (integrated condition). Interestingly, the current study showed that the self-managed condition performed equivalent to the integrated condition. A possible reason for this different result in this current study is the fact that, in contrast to the previous studies, learners in the self-management condition clearly understood how and why they were required to integrate text statements within the diagram to support their understanding. It can be inferred from the results that this led to the success of the self-managed condition. Furthermore, the participants in the self-managed condition had the same learning time as the participants in the two other conditions, yet were required to undertake an additional task to meaningfully integrate text with diagram by moving the text boxes to the appropriate parts of the diagram. The results reveal that this additional task did not adversely affect learning.

The findings from this study suggest that firstly teaching learners how to self-manage the split-attention effect may lead to significantly better test results compared to learning from traditional split source instructions and secondly, allowing learners to self-manage the split-attention effect may be as effective as presenting learners with instructor-managed integrated instructions. These findings have an important implication, as learners today can access a variety of instructional materials, both print-based and online, and many of which may not be optimally designed. Most importantly, when confronted with split-attention materials in a new learning tasks, learners who have been taught to self-manage split-attention materials can be expected to have an advantage over learners who have been taught with instructor-managed materials and do not know how to self-manage split-attention. This hypothesis needs to be tested in future research.

The results of this study have not only theoretical significance but also practical implications for learners' studying mathematical instructions. Based on extensive research in cognitive load theory, instructor managed integrated instructions have been shown to be very effective in reducing split-attention and supporting learning (Chandler & Sweller, 1991; Tindall-Ford, Chandler, & Sweller, 1997; Ward & Sweller, 1990). In this study, the self-management strategy had a similar positive effect on learning. The result suggests that teaching learners to manipulate instructional material to reduce search and meaningfully integrate related sources of information may support their learning. There may be a number of factors in self-management of split-attention that result in positive learning outcomes, being: (1) the eventual reduction in search of the learners' reorganized instructions; (2) the instructions being organized by the learner in a format that makes sense to them and; (3) the motivational factor in having control of instructions (Becker & Dwyer, 1994; Orvis, Fisher, & Wasserman, 2009).

There are several limitations to this study that could be addressed in future research. One limitation was that the school involved in the study was an all girls' school. Previous research in self-management by Agostinho et al. (2013) and Roodenrys et al. (2012) included both male and female learners. Although, it seems unlikely that the positive effect found for the self-management strategy is gender specific, future research should replicate the study with male participants.

Another limitation of this study was that only the short-term benefit of teaching self-management of split-attention was examined. Future studies should investigate the long-term benefits of teaching self-management strategies, for example by including a delayed transfer task to examine if self-management strategies would be transferable to another context.

There are many avenues for future research in the area of self-management of cognitive load. One includes investigating self-management of other cognitive load effects, for example learners could be taught how to remove redundant information to support their learning. Another path could be examining the effects of movement as an alternative explanation for the positive effect of the self-managed condition. According to the theoretical framework of embodied cognition (Glenberg, 2008), one would expect the movement of digital objects to reduce cognitive load and result in richer cognitive schemata (see e.g., Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). Future studies could test this by comparing conditions in which students can self-manage with or without movements.

Overall, computer-based learning environments are increasingly offering media resources as discrete "objects" containing images, text, animations, and videos, along with tools enabling interactions with these objects through annotation features such as highlighting, typing notes, and other means of building associations between pieces or "objects" of information. The intention of this current research is to provide an evidence base to inform generalizable applications of declaring explicitly to learners the underlying strategies available to reduce extraneous activities such as search, and increasing germane activities associated with schema acquisition.

## Conclusion

The research reported in this paper showed that learners who self-managed split-attention materials performed significantly better than learners who studied split-attention materials and performed as well as learners who studied instructor managed integrated instructions. Teaching learners how to self-manage split-attention is a new direction in CLT research. Today's students are increasingly accessing a variety of online information, thus research that examines how learners can manipulate online information to better help them learn is an important endeavor.

## Acknowledgements

This research was funded by the University of Wollongong's Research Council Small Grant Scheme, 2013.

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