European Journal of STEM Education, 1:1 (2016), 27-36
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ISSN: 2468-4368

Enhancing learners' problem solving performance in mathematics: A cognitive load perspective

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ABSTRACT

This paper reports on a pilot study that investigated the effect of implementing a context-based problem solving instruction (CBPSI) to enhance the problem solving performance of high school mathematics learners. Primarily, the pilot study aimed: (1) to evaluate the efficiency of data collection instruments; and, (2) to test the efficacy of CBPSI in relation to learners' problem solving performance. In this paper CBPSI refers to a teaching approach in which everyday problem solving knowledge and practices are uncovered when learners are exposed to tasks that give meaning to their everyday experiences. Given that the design of a pilot study lacked the inclusion of a control group, it is reasonable to conclude that the current design embraced elements of a pre-experimental research approach in which a one-group pre-test post-test design was followed. Participants consisted of a convenient sample of 57 Grade 10 learners who performed poorly in mathematics problem solving. The results of the study informed various conceptual and methodological revisions to strengthen the design of the main study, however, this paper reports only the effect of CBPSI on participants' problem solving performance. The post-intervention achievement test suggested that CBPSI was effective in substantially accelerating learners' problem solving performance (p<0.05). Using a cognitive load theory, it is possible to explain aspects of growth in learners' problem solving performance in relation to the conceptual notion of human cognitive architecture.

Keywords

problem solving
context-based instruction
cognitive load theory

Received: 03 Dec 2015
Revised: 29 Jan 2016
Accepted: 13 Feb 2016
Published online: 05 Mar 2016

DOI: 10.20897/lectito.201604

INTRODUCTION

Most researchers acknowledge that pilot studies provide useful pathways to enhance the design for the main studies. The pilot study that is reported in this paper formed a springboard for a successive (main) study that investigated the effect of a context-based problem solving instruction (CBPSI) on the performance of Grade 10 mathematics learners who performed poorly in mathematics problem solving (see, Dhlamini, 2012). The pilot study aimed: (1) to evaluate the efficiency of data collection instruments; and, (2) to test the efficacy of CBPSI in relation to learners' problem solving performance; however, only the latter (the enhancement of participants' problem solving performance) forms the focus this paper. CBPSI refers to "a teaching approach in which everyday problem solving knowledge of financial mathematics is uncovered when learners are exposed to tasks giving meaning to their everyday experience" (Dhlamini, 2011, p. 135). Certain topics in Grade 10 Financial Mathematics were taught to the study sample over a period of two weeks, and subsequently post-test and semi-structured interviews measured the problem solving performance of the participants or the efficacy of CBPSI.

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A cognitive load theory (CLT) framed this study (Sweller, 1988), and within this framework (CLT) the effect of a "worked-out examples" approach (Van Gog & Rummel, 2010, p. 156) influenced the design feature of CBPSI. CLT is an instructional theory that is based on some aspects of human cognition that are linked to problem solving performance (Sweller, 1988). In terms of CLT a worked-out examples approach refers to an instructional device that provides a model for solving a particular type of problems by presenting the solution in a step-by-step fashion (Van Gog & Rummel, 2010). It is intended to provide the learner with an expert's solution, which the learner can use as a model for his or her own problem solving. Given this background, this study applies the results of cognitive science research to design a treatment that teaches transfer explicitly, and with positive effects. In addition, the CLT assumptions are used to explain certain cognitive activities that characterized participants' problem solving performance actions during the treatment. In the next section I elaborate on the theoretical assumptions of CLT.

MODELLING PROBLEM SOLVING PERFORMANCE THROUGH CLT

Problem solving performance may be established within the broader theoretical framework of cognitive load theory (CLT). CLT uses current knowledge about the human cognitive architecture to generate instructional techniques that promote learning to enhance problem solving performance. Cognitive architecture can be defined as an underlying conceptual infrastructure that influences cognitive processes for an intelligent system, such as a human being (Langley, Laird & Rogers, 2007). In that way all human mental life and behaviour involve the cognitive architecture. For instance, perceiving everything around us involves using our cognitive system so that we can recognize and categorize what we see, hear, taste, touch and smell. In terms of learning, the basic premise of CLT is that learners' cognitive architecture consists of a working memory (WM) with severely limited processing capacity and duration when dealing with novel information (Fuchs, Fuchs, Finelli, Courey & Hamlett, 2004). Concerning its processing duration, almost all information stored in WM and not rehearsed is lost within 30 seconds (Paas, Van Gog & Sweller, 2010). Also, its capacity cannot deal with information more than about 7 elements of information simultaneously (Miller, 1956). Hence, if the WM capacity is exceeded while processing information then some, if not all, of that information will be lost. However, the limitations of the WM can only apply to new, yet to be learned information (Paas *et al*., 2010). Well-learned material, held in long-term memory (LTM), suffers from neither of these limitations when brought into WM (Ericsson & Kintsch, 1995). This means WM should be occupied by task-relevant operations, especially when dealing with complex material such as mathematics problem solving. Hence CLT pleads for a proper use of WM by means of efficient training.

According to CLT, human cognitive architecture also consists of an effectively unlimited long-term memory (LTM), which interacts with a WM to process information (Sweller, 1988). LTM has unlimited capacity and it can permanently store chunks of domain-specific skills and information structures known as schemas or schemata (Fuchs *et al*., 2004). Schemas categorize elements of information according to how they will be used, thereby facilitating accessibility later when they are needed for related tasks (Sweller, Merriënboer & Paas, 1998). In terms of CLT, the presence of schemas in LTM is considered a prerequisite because schemas reduce the amount of mental effort in WM that is needed to perform particular tasks (Van Gog & Rummel, 2010). Primarily, CLT focuses on how constraints on our WM help to determine what kinds of instruction are effective. According to CLT, teachers should design problem solving tasks that minimize the demand for processing in WM. Hence learning activities should minimize the processing and storage of information that is not directly relevant for learning in order to avoid taxing the WM processing capacity. To further illustrate the assumption of CLT, three types of CLT are distinguished.

Intrinsic cognitive load

This load refers to the complexity of the learning material that a learner intends to mentally learn (Van Gog & Rummel, 2010). However, the complexity is dependent on the intrinsic nature (difficulty level) of the learning material and also upon the learner's prior knowledge. Learner's prior knowledge has been considered in this definition because the size of meaningful information chunks that a learner can handle without taxing his or her WM capacity is dependent upon it (Van Gog & Rummel, 2010). Hence a problem solving task that is considered to be complex for a beginner may indeed be simpler for an expert. Therefore, to compensate for the deficiency in learner's prior knowledge, learning material of high complexity is enhanced when the interacting elements are taught in isolation and the relevant interactions are instructed later, suggesting that "intrinsic load can be manipulated by instruction" (Moreno, 2006, p. 171).

Extraneous cognitive load

Extraneous cognitive load (ECL) refers to the cognitive load that is imposed by instructional designs that require learners to engage in activities "that are not directed at schema acquisition" (Sweller, 1994, p. 299). This type of load is mainly dependant on the goal of instruction. For instance, when the goal of instruction is to construct problem solving schemas, the ECL is imposed if instructional materials contain texts and graphics that are difficult to integrate with each other (Chong, 2005). In this case learners may be forced to use much of their WM resources trying to establish coherence between the two sources of information. Consequently, little or no cognitive capacity will remain to foster learning and meaningful problem solving performance.

Germane cognitive load

Germane cognitive load (GCL) is also known as effective cognitive load. Unlike ECL, GCL is conceptualized as a load that contributes directly to learning. It is thereby influenced by the instructional designer. The manner in which information is presented to learners and the learning activities required of learners are relevant to what constitutes GCL (Chong, 2005). In the case of worked examples, self-explanatory activities could be conceptualized as a GCL.

Other researchers have argued that the three types of cognitive load are additive (see, Gerjets, Scheiter & Cierniak, 2009) in which case the sum cannot exceed the limits of the working memory capacity that is needed for learning to take place. Hence cognitive overload occurs if the sum of the three cognitive load types requires more working memory resources than the learner has at his or her disposal during learning (Gerjets *et al.*, 2009, p. 45). In Figure 1, I present a conceptual diagram to illustrate techniques to manipulate cognitive load to foster learning and problem solving performance.

Figure 1 may be used to guide the implementation phase of CBPSI of the pilot study. *Firstly*, CBPSI must be designed in a way that optimizes intrinsic load. This means CBPSI tasks should be at an appropriate level of complexity to match the learner's processing ability in the WM. This is achieved through sequential presentation of learning material, thus reducing the number of element interactivity that a novice memory has to simultaneously process at an instance. *Secondly*, extraneous load must be minimized (see the light blue colour in the middle block of Figure 1). In terms of Figure 1, more of the WM resources could be availed when the extraneous load is reduced. In the current study this is achieved by presenting learning materials grounded in learners' every day's experience (see, Dhlamini & Mogari, 2013). According to CLT, learning that takes place in familiar settings reduces the effects of cognitive load or the extraneous load. Hence effective learning takes place when extraneous load is kept at a minimum (Van Gog & Rummel, 2010). *Thirdly*, germane load (GCL) should be optimized to enhance the construction of problem solving schemas. In terms of Figure 1, GCL is optimized by keeping both intrinsic and extraneous loads at manageable levels. Once the extraneous load is effectively managed it can influence the levels of germane load.

Having observed that the three components of CLT are manageable, it is thereby reasonable to seek instructional techniques capable of substituting extraneous load (ECL) with germane load (GCL). Employing

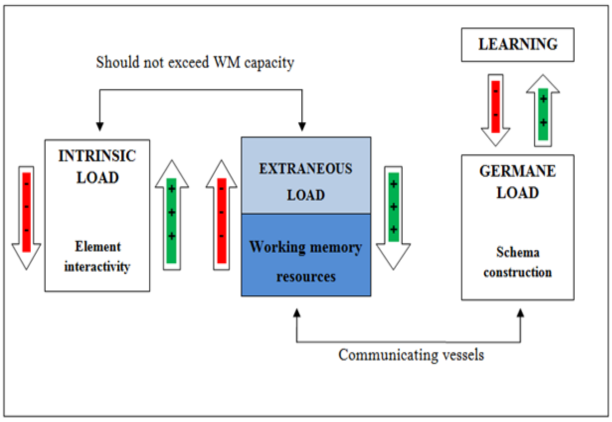


Figure 1. The influence of cognitive load on problem solving performance

Note: Green arrows (with positive signs) represent cognitive processes that support learning and enhancement of problem solving performance, and red arrows (with negative signs) represent cognitive processes that defeat learning and do not enhance problem solving performance.

Source: Dhlamini (2012, p. 81)

the worked examples approach and lowering the split-attention effect are instructional techniques that have been used to substitute the ECL with GCL (Paas, Van Gog & Sweller, 2010; Van Gog & Rummel, 2010).

THE PILOT STUDY

One of the aims of the pilot study was to promote Grade 10 learners' problem solving performance in mathematics. The study selected certain topics of Financial Mathematics, which covered the following themes: simple and compound interest, hire purchase, inflation and exchange rates. The choice of the topics was motivated by their perceived challenging nature to Grade 10 mathematics learners. When teachers were asked about topics that gave learners problems topics in Financial Mathematics were prominently listed (Dhlamini & Mogari, 2013). Learners' socioeconomic background, which was a township in this case, presented a context to generate effective instructional conditions for the study. Using CLT assumptions this paper conceives learning (enhancement of problem solving performance) as the construction of learners' problem solving schemata.

In terms of this definition, learners' problem solving performance would then be conceived as the ability to retrieve information in long-term memory. It seems various conditions affect the ability to retrieve information. According to Tulving and Thomson (1973, cited in Fulcher, 2003), the best conditions for retrieval are those that are most similar to those that are depicted during learning. According to CLT, learning that occurs in familiar settings ameliorates cognitive load associated with this process. Hence learners' real-world experiences presented a useful context to promote participants' problem solving performance in this study (see, Dhlamini, 2011).

Study design

Due to logistical constraints the design of this pilot study lacked the inclusion of a control group; hence it embraced elements of a pre-experimental research approach in which a one-group pre-test post-test design was followed. Semi-structured interviews and in-between problem solving discussions accounted for the results of the pre-experimental design.

Study sample

A convenient sample of 57 Grade 10 mathematics learners drawn from a township setting in the Gauteng[1] province of South Africa participated in the study. The mean age of the participants was 18.44(SD=0.74). The profile of the school from which the sample was drawn highlighted aspects of poor performance in mathematics problem solving. The school had achieved a mere 31.3% in Grade 12 end-of-the-year mathematics results of the year that preceded the pilot study, and this indicator seemed to be a trend in the last three years.

Instruments

The principal instrument for data collection was a standardized Grade 10 Functional Mathematics Achievement Test (FMAT). The FMAT was developed through months of iterative processes of acquiring existing items from classroom teachers, previous Grade 10 examination question papers, state-approved textbooks, obtaining feedback from subject specialists and advisers, and conducting repeated content validity assessments. Local subject specialists, teachers and mathematics Head of Departments from participating schools helped to revise test items to ensure they were aligned to learners' realistic context (see, Dhlamini & Mogari, 2013). The test was marked out of 60 (See Table 1).

Semi-structured were constructed and conducted according to Cobb and Steffe's (1983) principles of clinical interviews. Face, content, construct and convergent validity were used to validate instruments. For the achievement test this was achieved through an expert panel in mathematics education and research. To test the stability (consistency) of a pre- and post-test measure a test-retest reliability was computed and subsequent results confirmed the reliability of a test (r=0.92) to measure learners' problem solving performance.

Table 1. Classification of learners' achievement test scores

Criteria	Code	Description
Low-performing	LO	Below 24 marks
Average-performing	AV	Between 24 and 42 marks
High-performing	HI	Above 42

[1] Gauteng is one of the nine provinces in South Africa.

Instructions and intervention

Worked-out examples

The potential of more robust learning and enhancement of problem solving performance was exploited with several worked-out context-based problem solving examples. All worked-out examples contained a problem with a modelled procedure for the solution. Sweller and his colleagues found that providing learners with many worked-out examples is more effective than providing them with a few worked examples followed by instruction (Cooper & Sweller, 1987; Sweller & Cooper, 1985). In the pilot study a worksheet with examples was given to learners at the beginning of instruction. Learners worked with peers in groups to study examples and solve problems. Assistance was provided when it was needed. The worked-out example approach was used to demonstrate problems such as the one in Example 1.

In terms of mathematical representation problem activities such as Example 1 may result in a *'reversal error'* for learners where they may write **P=4C** instead of **C=4P** (see, Cooper, 1986; Wollman, 1983). In terms of Example 1 learners may be prone to confuse the *principal value* (**P**) with the *future value* (**A**), or vice versa. They may write **A**=R1 200 and **P**=R2 600, instead of **A**=R2 600 and **P**=R1 200. Also, due to their inadequate prior knowledge learners may spend time searching for cognitive mechanisms to match numbers with related variables. According to CLT, this process is cognitively demanding and may be executed at the expense of mental resources that could otherwise be allocated to learning and productive problem solving performance. In contrast, if learners are exposed to worked-out examples instruction they do not spend time searching or solving the problem, they rather devote all the available cognitive capacity to studying the worked-out solution procedure and constructing a cognitive schema for solving similar problems (Van Gog & Rummel, 2010).

An amount of R1 200 accumulates to R2 600 after 3 years.
Find the interest rate if the investment earned simple interest.

Example 1. An item from the achievement test (FMAT)

Split-attention effect

Another feature of CLT that was considered when implementing the CBPSI is the "split-attention effect" (Paas *et al.*, 2010). Split-attention effect is the process of attending to two distinct sources of information (Paas *et al.*, 2010), that is, simultaneously dividing ones' attention. The unnecessary visual search associated with the split-attention effect may heighten learners' cognitive load. An alternative instructional format to have all information physically located together may reduce the effect of split-attention, and hence facilitate the problem solving performance. To test the influence of the split-attention effect on learners' context-based problem solving performance a '*split-attention detector*' activity was designed for this study (see, Example 2 & Example 3). The purpose of the activity in Example 2 and Example 3 was to use its outcome to craft the design of instructional materials for the experiment. In a split-attention activity that was given to the participants, one group of the class was given a context-based problem solving task in which both the problem and the subsequent problem-related questions were written on the same side of the A4 page (See Example 2). The other group in the class was given the same task, but the problem was placed on one side of the A4 while the questions appeared on the flip side of the page (See Example 3). The purpose of this task was to observe the influence of a split-attention effect on learners' problem solving performance to maximize the efficiency of CBPSI.

The results of the activity in Example 2 and Example 3 showed that learners who were given context-based problem-questions on the same page experienced minimal cognitive-related challenges compared to learners subjected to a relatively more inducing split-attention conditions (see comparative discussion of these results in Dhlamini, 2012, p. 179).

At the end of a split-attention activity questions were asked to explore the split-attention encounters of participants in their respective conditions. Responses suggested whether or not the respondent experienced cognitive load.

Some of the questions asked to the learners are provided below:

Q: Was it easy or difficult for you to do this task?

Most respondents subjected in the split-attention induced conditions acknowledged that it was difficult to work in their conditions. A follow-up question was advanced:

Q: Why was it difficult for you to do this task?

Side 1 of page 1 (A4)

Problem

The table below shows the exchange rate of the Rand (R) against other countries. Use the information below to answer the questions that follow.

Currency	One foreign unit = R
Euro €	9.178
UK £	14.484
US $	9.925
Australia $	5.556
Botswana Pula	1.621
Canadian $	6.452
Hong Kong $	1.274

Questions

Sipho won a competition where he can fly to three international destinations free of charge with spending money. The destinations he chose were Germany (€), Hong Kong ($) and England (£). He was allocated €9 000, $30 000 and £2 500 for Germany, Hong Kong and England respectively.

1. 1. Use the exchange rates in the previous page to calculate the total amount Sipho had been allocated in Rands.
2.
3. 2. If Sipho were to fly to Botswana, Canada and Australia with allocations of 9 500 Pula, $15000 and $21 500, respectively. How much will be his total allocation for this trip?

Example 2. A task in which the problem and questions appear on the same activity page

Side 1 of page 1 (A4)

Problem

The table below shows the exchange rate of the Rand (R) against other countries. Use the information below to answer the questions that follow.

Currency	One foreign unit = R
Euro €	9.178
UK £	14.484
US $	9.925
Australia $	5.556
Botswana Pula	1.621
Canadian $	6.452
Hong Kong $	1.274

Side 2 (flip side) of page 1 (A4)

Questions

Sipho won a competition where he can fly to three international destinations free of charge with spending money. The destinations he chose were Germany (€), Hong Kong ($) and England (£). He was allocated €9 000, $30 000 and £2 500 for Germany, Hong Kong and England respectively.

1. Use the exchange rates in the previous page to calculate the total amount Sipho had been allocated in Rands.
2. If Sipho were to fly to Botswana, Canada and Australia with allocations of 9 500 Pula, $15000
3. and $21 500, respectively. How much will be his total allocation for this trip?

Example 3. The problem and questions appear on different sides of the same activity page

One learner responded with a question:

Learner 1 (L1): But meneer[2] why did you write questions in another side?

Another learner: L2: It was not fair for us because we were not working in one page.

The responses of L1 and L2 represented a section of participants who were subjected to the Example 3 condition. It is reasonable to conclude that participants in Example 3 experienced more cognitive load, which seemingly hindered their problem solving performance. In addition, most learners in Example 2 took longer time to complete the task. The results depicted a substantial time-related advantage for participants in the integrated versions of the task (Example 1). From a CLT perspective, unnecessary visual search caused by the split-attention effect may heighten learners' cognitive load, and WM resources needed for learning are used to counter-act the effects of split-attention. To reduce the WM load the design feature of CBPSI presented

[2] The word meneer is an Afrikaans word for Mister (Mr). In South Africa it is common for learners to refer to their male teachers as meneer, as a sign of respect and recognition of his teaching role.

context-based tasks by physically integrating all aspects of the problems. For instance, there was no separate sheet for problem formulae. All formulae were integrated in problem sheets. Given these guidelines, all activities were meaningfully designed to accelerate participants' problem solving performance. For instance, the exchange rates section normally includes an exchange currency rates table. In the pilot study, the table, the problem and the questions were all integrated to minimize the split-attention.

RESULTS AND ANALYSIS

In this section participants' problem solving performance is analyzed in terms of the achievement test performance (results) and semi-structured interview responses.

Achievement test

The level of problem solving performance was measured by the performance in the achievement test (FMAT). The pre-test (M=18.54; SD=6.827; n=57) and post-test (M=21.35; SD=7.328; n=57) were computed. Given that the mean scores of the pre-test were low it was assumed that learners were in their early stages of problem solving performance. At the end of intervention the increase of problem solving performance from the pre-test performance to post-test performance was observed. To determine the effectiveness of CBPSI the mean scores of the pre- and post-tests were compared using a t-test at the significance level of 0.05 (See Table 2).

The results in Table 2 suggest that participants' problem solving performance in a context-based problem solving achievement test (FMAT) improved significantly (p<0.05) as a function of the experiment. It is reasonable to conclude that the CBPSI designed to improve learners' problem solving performance is effective.

Learners committed several errors at the initial stages (pre-test) of the pilot experiment. For instance, in question 2.2 of FMAT certain types of errors were observed, namely: (1) two types of reverse errors; and, (2) incorrect choice of formula. Example 4 is used to illuminate the emergence of errors in (1) and (2) and sampled

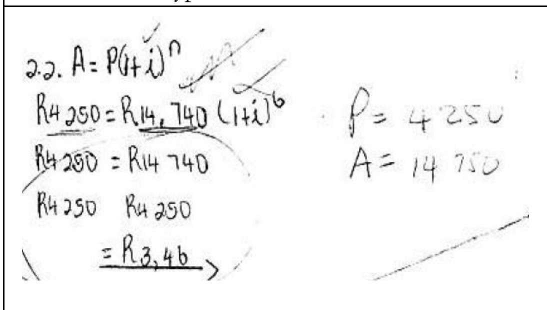
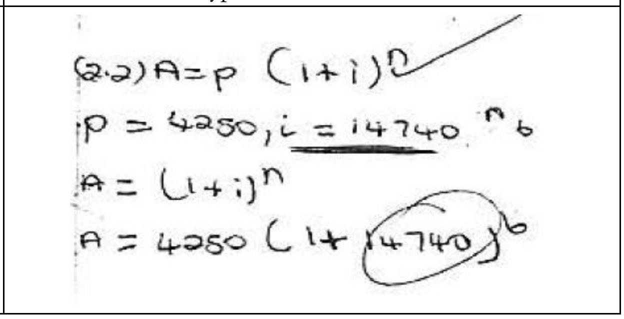
Table 2. Statistical results of the t-test analysis for the achievement test (FMAT)

Test	Group	n	$\bar{x}$	SD	SEM	t	p-value
Pre-test	Grade 10	57	18.54	6.827	0.90	2.116	0.0366
Post-test	Grade 10	57	21.35	7.328	0.97		

**Significant at 0.05 level*

> ***Q 2.2:*** *R4 250 is invested for 6 years and grows to R14 740. Find the interest rate if interest is compounded annually.*

Example 4. Question 2.2 (Q 2.2) of the achievement test (FMAT)

<table>
<tr><th>Type 1 of reverse error</th><th>Type 2 of reverse error</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Example 5. Two types of reverse errors depicted by test-takers in a pre-experimental phase

participants' erroneous responses.

The problem information that is provided in Example 4 can possibly be arranged as follows: $\boldsymbol{A}$=14 740; $\boldsymbol{P}$=R4 250; $\boldsymbol{n}$=6 years; $\boldsymbol{i}$=?, and the formula $\boldsymbol{A}=\boldsymbol{P}(1+\boldsymbol{i})^n$ could be used. Example 5 shows samples of participants' scripts with "*reverse errors*" in two versions:

In **type 1 error** the learner confused ***P*** and ***A*** values (Cooper, 1986). Another type of reverse error is reflected in **type 2 error**. Participants who committed the type 2 error incorrectly assigned the value of ***P*** to ***i***. Of the 57 study participants 31(54%) committed the type 2 error. When probed on their tendency to commit type 2 error, one learner responded:

> L3: "If you take money to the bank you get interest. The money you get in the end is interest, bigger than your first money".

Most participants seemed to agree with the L3 response as they nodded in silence. It appeared to these learners that a phrase such as "*accumulated amount*" referred to the interest that they associated with "***i***".

Another type of error (**type 3**) that emerged in Example 4 was learners' inability to select the correct formula for problem solving purposes (see, Example 6).

The test taker in Example 6 selected an incorrect formula (*simple interest formula* instead of *compound interest formula*). In addition, the participant in Example 6 committed a **type 2 error** by replacing "***A***" with "***i***". Of the 57 participants, 19(33%) committed a **type 3 error**. These findings suggested that learners lacked effective problem solving skills at the beginning of the experiment and their subsequent problem solving performance was minimal.

Semi-structured interviews and in-between activity questions

Subsequent interviews corroborated the results of the achievement test. There was evidence that learners were progressing in problem solving performance. For instance, during a problem solving activity, whenever an extended period of silence was observed the researcher asked the learner: "*What are you thinking?*". Learners' responses demonstrated their attempts in linking novel problems to previously encountered problems (worked-out examples). For instance, this was one learner's response to the researcher's question.

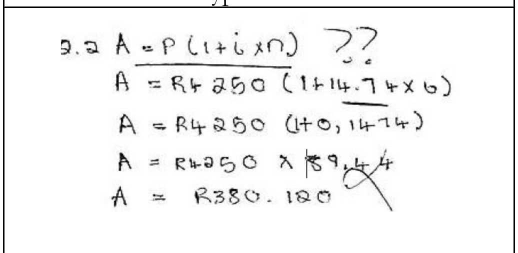
> L4: "I'm trying to think how we did the same problem sir".

According to Cobb and Steff (1983), the kinds of questions asked here by the researcher only cause minor interruptions of learners' actions and do not threaten the data's validity. Periods of self-reflection may indicate instances where learners are monitoring and assessing their actions to aid their understanding of the problem (Cobb & Steff, 1983). Given this background the researcher continued to probe study participants as they worked through context-based problems. Learners' responses were coded in terms of whether they reflected schema. For an example, the L5 to L7 responses were coded as reflecting schema construction (needed to enhance problem solving performance):

> L5: "This problem reminds me of an earlier problem that we solved".
> L6: "I'm using the same step as in that problem".
> L7: "I'm solving this one like that one" (referring to a previously solved worked-out example).

It was observed that when faced with novel context-based problems, study participants reported thinking about how an earlier problem (example) had been solved. The responses of L5 to L7 demonstrate that schemas influenced their problem solving behaviour and performance on problems that fell within the scope of newly constructed related schemas. These results replicate Cooper and Sweller (1987) in which they questioned Grade 8 learners as they worked through the novel algebra problem. Respondents demonstrated gains in schema constructions through their responses.

Type 3 error



Example 6. Type 3 error in which an incorrect selection of the formula was observed

In the current study when one learner was asked about the context-based problem solving approach she responded: "*I think it was easy to solve problems after we did the examples*". In terms of CLT, the latter response suggested learners experienced reduced levels of cognitive load during a CBPSI. According to Van Gog and Rummel (2010), example-based instruction, which characterized the design of CBPSI, should minimize learners' use of cognitive resources in activities that are not relevant to schema acquisition and automation (sources of ICL and ECL) and maximize learners' use of cognitive resources in germane activities (sources of CL) within the limits of WM capacity.

SUMMARY AND CONCLUDING REMARKS

Using the assumption of CLT it is possible to provide plausible explanation for the observed learners' accelerated problem solving performance. In an earlier discussion it was demonstrated that complex tasks such as problem solving are high in element interactivity (extraneous load). Using this knowledge and the results of this pilot study, it may be argued that many of the elements involved in solving context-based problem solving tasks in financial mathematics interact with each other and so cannot be considered in isolation. Many learners are reported to experience a lot of cognitive load when solving this topic in mathematics. Most problems in financial mathematics are presented in real-world world contexts. This study has demonstrated that element interactivity may appear to be very high if the context of the problem is not familiar to test-takers thus heightening the extraneous load (ECL) that may hamper the problem solving performance (See Figure 1).

In financial mathematics problems learners not only have to identify relevant information, but also simultaneously match specific key amounts with their corresponding symbols and also construct relationships between them. This process might pose challenges for a novice problem solver, which was represented by most of the participants at the beginning of the pilot study (See Table 3 for pre-test mean scores). According to CLT and Figure 1, a rise in ECL reduces WM resources needed for schema construction and automation. To alleviate these cognitive challenges the design feature of CBPSI embraced the following techniques: (1) the effect of the split-attention was minimized; (2) participants' real-world context was meaningfully incorporated during problem solving interactions; and, (3) the worked-out examples approach was integrated to the intervention instruction (CBPSI). In terms of CLT, all of these instructional techniques contribute effectively to learning and development of problem solving performance (Van Gog & Rummel, 2010).

The results of the pilot study demonstrate that CBPSI is effective in accelerating the problem solving performance of participants. However, these results may not be conclusive because the design of this study lacked the inclusion of a control group. The major shortfall of the design of this pilot study is that it can only provide the research with an option to assume that the observed differences in pre- and post-test scores are due to treatment (intervention instruction, CBPSI). It is possible that factors such as maturation, pre-test sensitization or treatment-instrument interaction could have also played themselves out during the course of the experiment, thus rendering the study suspect to rival explanation for the observed results. To mitigate these shortcomings the subsequent main study followed a non-equivalent control group design with pre- and post-measures.

REFERENCES

Case, A. and Deaton, A., 1999. School inputs and educational outcomes in South Africa. *Quarterly Journal of Economics*, pp.1047-1084.

Chong, T.S., 2005. Recent Advances Cognitive Load Theory Research: Implications for the Instructional Designers. *Recent Advances in Cognitive Load Theory Research*.

Cooper, M., 1986. The Dependence of Multiplicative Reversal on Equation Format. *Journal of Mathematical Behavior*, *5*(2), pp.115-20.

Cooper, G. and Sweller, J., 1987. Effects of schema acquisition and rule automation on mathematical problem-solving transfer. *Journal of educational psychology*, *79*(4), p.347.

Dhlamini, J.J., 2012. Investigating the effect of context-based problem solving instruction on the performance of learners. *Unpublished doctoral dissertation. University of South Africa, Pretoria, South Africa. Available from ht tp://hdl. handle. net/10500/9739*.

Dhlamini, J.J., 2011, July. Context-based problem solving instruction to induce high school learners' problem solving skills. In *Proceedings of the 17th Annual National Congress of the Association for Mathematics Education of South Africa* (Vol. 1, pp. 135-142).

Dhlamini, J. and Mogari, D., 2013. The effect of a group approach on the performance of high school mathematics learners: original research.*Pythagoras*, *34*(2), pp.1-9.

Department of Education (DoE), 2003. National Curriculum Statement Grades 10-12 (General): Mathematical Literacy. Pretoria: Department of Education, South Africa.

Ericsson, K.A. and Kintsch, W., 1995. Long-term working memory.*Psychological review*, *102*(2), p.211.

Fuchs, L.S., Fuchs, D., Finelli, R., Courey, S.J. and Hamlett, C.L., 2004. Expanding schema-based transfer instruction to help third graders solve real-life mathematical problems. *American Educational Research Journal*, *41*(2), pp.419-445.

Fulcher, E., 2003. *Cognitive psychology*. Learning Matters.

Gerjets, P., Scheiter, K. and Cierniak, G., 2009. The scientific value of cognitive load theory: A research agenda based on the structuralist view of theories. *Educational Psychology Review*, *21*(1), pp.43-54.

Langley, P., Laird, J.E. and Rogers, S., 2009. Cognitive architectures: Research issues and challenges. *Cognitive Systems Research*, *10*(2), pp.141-160.

Macrae, M., 1994. A legacy of apartheid: the case of mathematical education in South Africa. *International Journal of Educational Development*,*14*(3), pp.271-287.

Paas, F., Van Gog, T. and Sweller, J., 2010. Cognitive load theory: New conceptualizations, specifications, and integrated research perspectives.*Educational Psychology Review*, *22*(2), pp.115-121.

Sweller, J., 1994. Cognitive load theory, learning difficulty, and instructional design. *Learning and instruction*, *4*(4), pp.295-312.

Sweller, J., 1988. Cognitive load during problem solving: Effects on learning.*Cognitive science*, *12*(2), pp.257-285.

Sweller, J. and Cooper, G.A., 1985. The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction*,*2*(1), pp.59-89.

Sweller, J., Van Merrienboer, J.J. and Paas, F.G., 1998. Cognitive architecture and instructional design. *Educational psychology review*, *10*(3), pp.251-296.

Van Gog, T. and Rummel, N., 2010. Example-based learning: Integrating cognitive and social-cognitive research perspectives. *Educational Psychology Review*, *22*(2), pp.155-174.

Van der Berg, S., 2007. Apartheid's enduring legacy: Inequalities in education. *Journal of African Economies*, *16*(5), pp.849-880.

Wollman, W., 1983. Determining the sources of error in a translation from sentence to equation. *Journal for Research in Mathematics Education*, *14*(1), pp.169-181.