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Wikis: Developing pre-service teachers' leadership skills and knowledge of content standards

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ABSTRACT

In this initial phase of our multi-year research study we set out to explore the development of leadership skills in our pre-service secondary teachers after using an online wiki, Wikispaces. This paper presents our methods for preparing a group of 13 mathematics and 3 science secondary pre-service teachers to demonstrate the essential knowledge, skills and dispositions of beginning teacher leaders. Our findings indicate the pre-service teachers' overall satisfaction with demonstrating leadership through collaborative practices. They were successful in these new roles as teacher/collaborator within the context of communication about content standards. Though the candidates participated in other collaborative tasks, this effort was noted for bringing together technology, content standards and leadership qualities that are critical for beginning teachers. Implications for addressing the pre-service teachers' development of leadership skills, as they become professional teachers will be shared.

Keywords

teacher leadership
STEM preservice education
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INTRODUCTION

Using wikis for communicating with peers is not new for many undergraduate students. For a particular group of 16 secondary pre-service teachers, it creates a unique method for developing and demonstrating leadership qualities. Wikis are defined as collections of sites on the web that can be easily edited online (Moskaliuk & Kimmerle 2009; Leuf & Cunningham 2001). The popular educational wiki site, Wikispaces, was utilized in a class of 13 secondary mathematics and 3 science pre-service teachers to share instructional products aligned with Common Core State Standards in Mathematics (CCSSM) and the North Carolina Essential Science Standards (NCESS) (Common Core State Standards Initiative 2010; NC Department of Public Instruction 2010).

As the instructors of a secondary education seminar course, we sought an innovative approach to allow pre-service teachers to develop and demonstrate teacher leadership skills in response to state teaching evaluation standards, the North Carolina Professional Teaching Standards (NCPTS) (NC State Board of Education 2007). These standards were written to guide the evaluation of practicing teachers. Bond (2011, p. 11) noted the limited amount of research on leadership for pre-service teachers and the critical need "to equip our pre-service teachers with the knowledge, skills, and dispositions for teacher leadership roles" in teacher education programs. We recognized the need to address the development of leadership skills with pre-service teachers before they become practicing teachers. Using the primary themes to demonstrate the leadership skills as described by York-Barr and Duke (2004, p. 282), we began to establish the tasks to support the development of the candidates. The themes are as follows: "continuing to learn about and demonstrate

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advanced curricular, instructional, and assessment practices; school culture and how to initiate and support change and developing the knowledge and skills to support the development of colleagues". The wiki class space, provided a learning community in which the pre-service teachers were able to build, edit, contribute, and share ideas related to their own instructional practices and resources grounded in curriculum standards. As noted by Twu (2009), the tool offers valued social interactions that occur in learning environments rich in both social and cultural perspectives. The instructional strategies explained by Twu (2009) indicate the vital role of the instructor in providing support for learners to interact, getting familiar with the tool, and communicating within this collaborative context.

We found that the tool offered a platform for the thoughtful exchange of ideas. Bringing together technology, content standards and leadership qualities, we developed a task to enhance the pre-service teachers' pedagogical and teacher leadership skills. This article addresses the role of using wikis as a tool in demonstrating knowledge of CCSSM, NCESS, NCPTS and the development of leadership skills by focusing on a design method used to teach pre-service mathematics and science teachers to plan effectively and demonstrate teacher leadership qualities.

LITERATURE

Why wikis? The decision to use Wikispaces was based on our personal interests in technology and experiences with using wikis and other Web 2.0 technologies in educational settings. We agreed the Wikispaces design and usability would serve as the platform for helping our pre-service teachers develop pedagogical and leadership skills. Wikispaces "makes collaboration and community building easy and encourages the use of a myriad of Internet resources, content, and tools (Wikispaces Classroom 2013). We found, as Désilets, Paquet and Vinson (2005), that it did not require any special software or hardware, which made it a viable choice for use in the course and in our high schools. The collaborative nature of the wiki classroom space made it a valuable technology for teaching and learning (Kohler & Fuchs-Kittowski 2005).

Another reason for selecting this particular wiki was its account properties. It allows users access to materials as long as the wiki is kept active, a benefit for both instructors and pre-service teachers. After setting up the class space, account users still have access to their work after completing the teacher education program. Former pre-service teachers are able to access materials, and continue to edit, collaborate and share with peers while they work in their own secondary classrooms. This technology, grounded in socio-cultural interactions, provides a continual space for instructors and students to construct, collaborate, edit and discuss instructional ideas (Twu 2009). Wikispaces for the leadership assignment allowed them to create the product, share it and provide comments on others' content on the site. Reinhold's (2006, p. 47) suggestion that "wikis facilitate collaborative shaping and sharing of knowledge" aided our decision.

METHOD

We designed the leadership assignment to address the curriculum standards for developing instructional resources using this tool. The assignment helped the pre-service teachers better understand teacher leadership qualities through reflective practices and sharing of resources with teachers. As a result of completing this assignment, the pre-service teachers were able to build confidence and skills through taking ownership in sharing knowledge with others. The assignment provided our pre-service teachers the opportunity to build on their understanding of the CCSSM and NCESS standards and shape how they shared resources. According to Evans (2006), wikis are tools that enable groups to harness their creative energy through shared knowledge. Each pre-service teacher created an individual page in the wiki showcasing their understanding of standards with a lesson plan and list of online resources. They subsequently shared their pages with their partnership teachers and peers for feedback. We were able to create a collaborative online community in which pre-service teachers were able to "generate online materials that reflect what they have learned and show connections between their prior knowledge, the course content, and their personal experiences" (Matthew & Callaway 2009, p. 52). The development of leadership skills resulted from the pre-service teachers' collectively taking ownership of their finished projects, sharing their work with others, and valuing the comments and contributions from others. Following a supported process to ensure they had quality teaching and learning from teacher leaders in the schools, led to this intended effect of improved instructional practices and quality leadership skills. Figures 1 and 2 show the layout of class wiki with student samples.

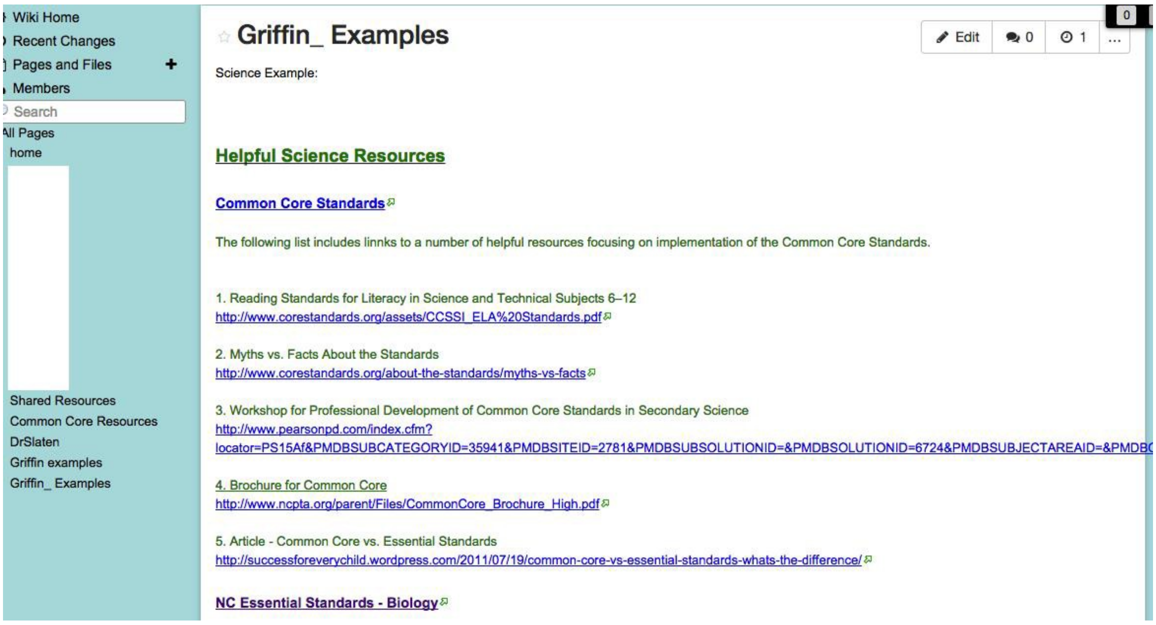

Figure 1. Wiki page science example (p. 4)

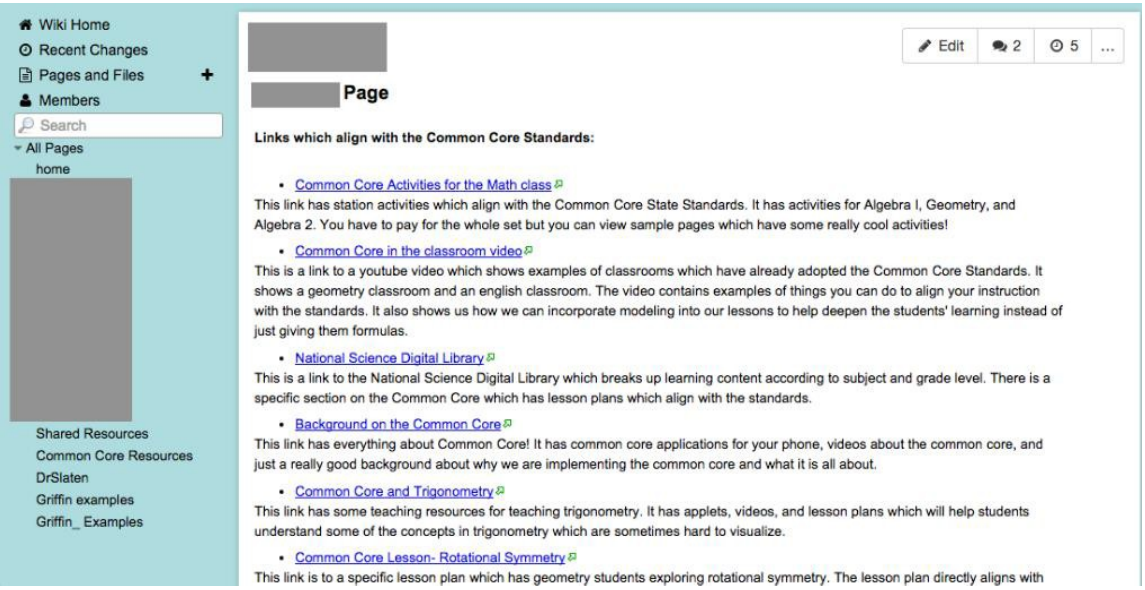

Figure 2. Wiki page mathematics example (p. 4)

The leadership assignment was designed to help pre-service teacher candidates in mathematics and science demonstrate Standard 1c of the NC Professional Teaching Standards, which require teachers to lead within the teaching profession. Based on this standard, all candidates should: "Strive to improve the teaching profession; contribute to the establishment of positive working relationships in the school; actively participate in and advocate for the decision-making structures in education and government that take advantage of the expertise of teachers and promote professional growth for all educators and collaborate with their colleagues to improve the profession" (NC State Board of Education 2007, p. 2). Being a teacher leader is an important quality for educators and in order for teacher candidates to pursue such an endeavor, they must be able to reflect upon, analyze, and share their interests, knowledge, skills and dispositions with others.

Using the guidelines provided and in-class tutorial on using the class wiki, the pre-service teachers were able complete the assignment based on sound pedagogy. The pre-service teachers were asked to complete an anonymous Likert scale perceptions survey item to assess their attitudes about using the tool and their confidence in demonstrating leadership qualities in the schools. They rated their confidence high with using the tool and satisfaction with leadership qualities demonstrated from the task.

The basis of the leadership assignment was to create an environment supportive of "collaborative shaping and the sharing of content and pedagogical knowledge" (Reinhold, 2006, p. 47). The presence of the wiki tool provided the caveat for the pre-service teachers to demonstrate the quality of a being a teacher leader in the teaching profession. It also allowed for a sustained learning environment through the reflective exchange of knowledge by pre-service teachers, instructors and partnership teachers. The tiered levels of participation in the assignment allowed the pre-service teachers to actively communicate with others who have common interests and commitment to the teaching profession. The task energized the thinking of our partnership teachers and provided the pre-service teachers with new roles in the internship process. Pre-service teachers were rethinking their commitment to the profession. It offered the pre-service teachers a "sense of collective responsibility" that is acquired only when one commits honesty (Ackerman & Mackenzie 2006, p. 70).

RESULTS

When presented with broader roles and responsibilities, pre-service teachers may redefine their own thinking about teaching and "when instruction is public, teachers learn about the power of collaboration for improving their practice" (Paek 2008, p. 12). The comments shared on individual products provided insight into how the materials could be effectively used in a secondary mathematics or science classrooms. Ackerman and MacKenzie (2006) assert the importance of allowing teacher leaders the opportunity to voice their opinions. The ability to post comments using the wiki enabled the pre-service teachers and their partnership teachers to state their opinions while remaining focused and share ideas to extend knowledge of content and standards.

Pre-service teacher comments (Pre-service Teacher Comments, 2012)

> I really like this matrices activity and I think it goes along well with the common core curriculum.
>
> I really like how you incorporated science into this activity as well. This may help peak certain students interests, particularly those who enjoy science. Great job!
>
> Hey, great resources. I'm not science but I liked the way you organized your page. Loved your lesson plan as well.
>
> Factoring is something many of my students struggled with especially since there are so many different techniques used to factor. I really think it is important to distinguish between the different techniques so that the students are using the easiest method for the given polynomial, which is why I really enjoyed this lesson.

Partnership teacher comments (Partnership Teacher Comments, 2013)

> Instead of giving the students just the table, go through and give them step-by-step instructions on how to calculate things and then they can plug it into the table."
>
> Have the students make the graph themselves instead of giving them the graphs. Overall this is a great discovery activity that relates new material to prior knowledge of inverses, which the students can see in their everyday lives.

Encouraging this exchange of ideas, the leadership assignment provided an ideal opportunity for pre-service teachers to develop and demonstrate leadership qualities. The pre-service teachers and partnership teachers were provided with a new outlet for collaboration and critical thinking. The success was due in part to its collaborative structure of engaging participants in conversations with influential support. The assignment created an opportunity for constructive feedback. The level and depth of feedback the pre-service teachers exchanged with one another was rather surface, lacking in constructive criticism, whereas the partnership teachers and instructors provided more directed feedback. Many pre-service teacher comments included "I like" or "I love". This pattern of feedback constrained their engagement in critical thinking and reflective practices with their peers.

DISCUSSION

Lewthwaite (2006) noted, in his study of science teacher leaders, the following factors are needed to develop teacher leader qualities: "professional knowledge, teaching efficacy, interest, motivation and commitment" (p. 343). The pre-service teachers in this course were able to demonstrate all of these traits through the use of this tool. The multi-leveled exchange of ideas by the pre-service teachers, partnership teachers and instructors led to a successful teacher-leadership practice that can be modeled in other discipline areas.

Overall, the pre-service teachers were successful in completing the leadership assignment and demonstrating the teacher leadership quality of leading the profession. The noted success of implementing this assignment in the course was the novel platform of innovative thinking and exchanges of content knowledge and pedagogy. This led to energized thinking by the pre-service teachers, their partnership teachers, and the course instructors through the sharing of new ideas and practices. The wiki class space provided the ideal platform for formative comments on instructional content developed by the pre-service teachers. The pre-service teachers commented they took this opportunity to share their wiki pages with other novice educators and teachers in their placement schools, indicating a rethinking of their roles within the schools. Through this opportunity the pre-service teachers were able to lead and rethink their commitment within the teaching community. As Ronald (2001) suggested in his work on teaching communities, the wiki in this setting also supports the idea that "teaching always occurs in a community of other teachers, as well as in a community of learners" (p. 318). We are pleased with the results and the confidence of the pre-service teachers in using this tool to demonstrate leadership traits.

Limitations of time and coaching on constructive feedback impacted the pre-service teachers' sharing and conversations with peers, partnership teachers and others. Pre-service teachers need further instruction on providing constructive feedback to their peers. There is a need for more research on the use of wikis in secondary education programs to determine the level of influence this could have on pre-service teachers' development of leadership characteristics.

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Quantitative evaluation of flexibility in undergraduate engineering curricula in the United Arab Emirates

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ABSTRACT

In academia, smooth progression of students significantly depends on the way curricula are developed and organized. Curricula or study plans with high degree of interconnectivity between courses, multiple prerequisites, and hierarchically structured courses tend to complicate the smooth progress of the enrolled students. In this work, a rigorous quantitative relaxation indicator, developed and published elsewhere by the first author, has been applied to quantify the degree of stiffness and rigidity in undergraduate engineering curricula at the American University of Sharjah (AUS), the University of Sharjah (UOS), United Arab Emirates University (UAEU), and the Petroleum Institute (PI), which are the leading universities in the United Arab Emirates. Results indicate high rigidity (low relaxation indices) due to high degree of interconnectivity between courses, specifically in the second year of the study plans. The chemical engineering curriculum at PI exhibited the least flexibility due to very strong pre-and-co-requisite ties while the civil & environmental curriculum at UAEU showed the highest flexibility. The curricula considered require immediate attention and reorganization in order to facilitate smooth sequential progress of the students from one semester to another. A list of courses that require relaxation of strong pre-and co-requisites ties has been presented for each curriculum.

Keywords

study plan
curriculum
pre-requisites
co-requisites
curriculum organization

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INTRODUCTION

In order to obtain a higher education degree, university or college students are required to pass all the courses within their respective study plan or curriculum. In higher education, procrastination and time investment have become important concerns in the study of student performance and academic progress. A considerable proportion of research on student performance and academic progress has focused on individual differences between the students in terms of time management and procrastination (Hulst & Jansen, 2002). The relationship between procrastination and academic performance has been studied and discussed extensively in literature (Schouwenburg, 1992; Johnson & Bloom, 1995; Macan, 1994; Nonis, et al., 1998; Milgram, et al., 1992; Milgram, et al., 1995; Senécal, et al., 1995). However, in recent years, academic researchers have highlighted that academic performance does not solely depend on the student characteristics but also depends on the organization of the curriculum. In fact, institutes in higher education may improve students' progress and reduce procrastination by efficient curriculum structure (Hulst & Jansen, 2002; Darwish, 2011). Study progress has been shown to be affected by many curriculum-related factors. According to Crombag et al. (1975), students adjust their study behavior to the way the curriculum or study plan is organized. Other studies considered the effect of the academic calendar on the study progress of the students (Vaughan & Carlson, 1992; Jansen, 1993). It was observed that the study progress is slower in two- or three-

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semester periods than in study programs that involve six periods of seven weeks. Hulst & Jansen (2002) also studied effect of curriculum organization on the study progress. A hypothesis was formulated and tested about specific curriculum characteristics that can affect the academic progress and performance of the students. These characteristics included the spread of study activities over the years, the instruction and teaching characteristics, the examination characteristics, and the overall coherence of the program. The study highlighted that study progress is better in coherent programs comprising a relatively small number of theoretical courses rather than in a scattered program that comprises larger number of different courses. Also, the study highlighted that higher number of theoretical courses result in poor study progress of the students.

In a typical curriculum, courses are interlinked to some previous and following (pre-requisite) courses, or co-linked to some courses in the same semester (co-requisite). In the case of engineering study plans, the high degree of technical interdependence of course contents and the pre-and-co-requisite issues tend to complicate the smooth progression of students from one semester to another. These issues arise as a natural phenomenon since the engineering courses are hierarchical and sequential in nature. Probable delay in graduation may occur if a student fails a pre-requisite course that controls many other courses in the subsequent semesters. All over the world, engineering curricula are being subjected to revision and modifications in order to meet the pressing emerging issues such as strong scientific foundation, adequate social science requirements, strong exposure to ethics, good communications skills, enhanced technical communications, strong team spirit, and distance learning (Meyer & Jacobs, 2000; Krizan, 2000; Hubka, 2000). However, little attention is paid to the flexibility and the interlinking between the courses in the resulting study plans. This has resulted in development of study plans that pose difficulties even to good students in terms of ease of progression in the study program.

Recently, there have been some attempts to revise engineering undergraduate curriculum to make engineering disciplines more capable of attracting and retaining students and to ease the severity of interlinking of courses in the curriculum. For example, in a project called "Deconstructing Engineering Education Programs", an attempt was made to offer greater flexibility to the students by reducing and reordering the prerequisite structure of the mechanical engineering undergraduate curriculum (Busch-Vishniac, et al., 2011). Eder & Hubka (2005) suggested that a curriculum or study plan should meet the educational objectives in a previously-articulated means through the choice of the educational material and the teaching constraints and regulations. A study plan, therefore, should define the topics or subject matter to be presented, their volume in terms of scope and detail, and the sequence in which they should be instructed. It should also define relationships among the topic regions and demonstrate to the students how these topics relate to one another. Explaining the importance of flexibility and adaptability in engineering education, Krasniewski (2003) suggested that study plans should be flexible and should provide freedom to the students in designing his/her individual program of study by avoiding restrictions due to an excessive number of compulsory or interlinked courses. More recently, Alpay (2013) highlighted the importance of curricula flexibility and breadth in attracting engineering students. Other researchers proposed a novel approach for designing flexible curricula (Vodovozov & Raud, 2011; Vodovozov & Raud, 2012). The study suggests the use of a new tool called an educational thesaurus in order to improve the quality and effectiveness of the learning process. An extreme care is, therefore, required while developing curricula in engineering and science-discipline majors. A special consideration is required to avoid multiple prerequisites, high degree of interconnectivity, and hierarchical structure of the courses. Any curriculum stressed by pre-and-co-requisites will render that study plan rigid and will complicate smooth progression of the students.

The aim of this study is to apply the quantitative indicator of flexibility, developed by Darwish (2011), to several engineering curricula in three of the leading universities in United Arab Emirates. Strong ties of pre-and-co-requisites have been highlighted and the degree of rigidity in the selected engineering curricula has been calculated using a quantitative (relaxation) index. Finally, the stressed course in each curriculum have been highlighted and improvements in the structure of the selected curricula have been suggested in order to facilitate smooth students' progression.

METHODOLOGY

The quantitative indicator of curriculum flexibility developed by Darwish (2011) has been applied in this study. The prediction of curriculum flexibility is based on the calculation of two distinct indices for each course in a study plan. These two indices have been named relaxation index (*RI*) and in-tandem chain index or simply chain index (*CI*) and are developed based entirely on logic. A description of these quantitative indicators of curriculum flexibility is presented in this section.

Relaxation Index (RI)

In a typical curriculum, a highly stressed course is the one which is linked or connected to many pre-and-co-requisites in the current or previous semesters. On the other hand, a stand-alone course with no connections with any other course in the curriculum is considered as a totally relaxed course. In fact, each course in a certain semester can be considered as a nodal point that is connected to former (pre-requisite) courses in the previous semesters, subsequent (post-requisite) courses in the upcoming semesters, or current (co-requisite) courses in the same semester. These connections can be assigned numerical values between zero and one, called connection strength (*CS*), based entirely on logical argument. Table 1 summarizes the logical values of *CS* for different connection scenarios.

The relaxation index (*RI*) for a given course in a certain study plan is calculated from the connection strength values as follows:

$$RI = 1 - \frac{\sum_{k=1}^{k=NC} CS_k}{NCS} \qquad (1)$$

Where *NC* is the number of connections associated the course under consideration, CS_k is the value of the *CS* for connection *k*, and *NCS* is the total number of courses in the semester of the course under consideration. The value of *RI* will be 1 for a standalone course that is not connected to any other course in the same or other semesters. On the other hand, a totally stressed course will have *RI* value of zero. The number of connections with other courses in directly adjacent semesters for a totally stressed course will be equal to the number of courses in the semester under consideration. In addition, the value of *RI* can also be negative. This is true for an overstressed course that has higher number of connections than the number of courses in the semester under consideration.

An example for the calculation of *RI* is presented in Table 2 by creating a network structure for the pre-, post-, and co-requisites. In Table 2, the first course in the third semester is considered as a node and numerical values of *CS* are assigned based on the connection scenarios in Table 1. The course under consideration has two pre-requisites. The first pre-requisite occurs in the second semester (*CS* = 1). While the second pre-requisite occurs in the first semester (*CS* = 0.5). In addition, the course itself is a pre-requisite for two other courses, one course in the subsequent semester (*CS* = 1) and another course in the sixth semester (*CS* = 0). Also, the course is a co-requisite for another course in the same semester (*CS* = 0.5). Using Eq. (1), the numerical value of relaxation index (*RI*) for this course is:

$$RI = 1 - \frac{\sum_{k=1}^{k=NC} CS_k}{NCS} = 1 - \frac{1+0.5+1+0+0.5}{5} = 0.4 \qquad (2)$$

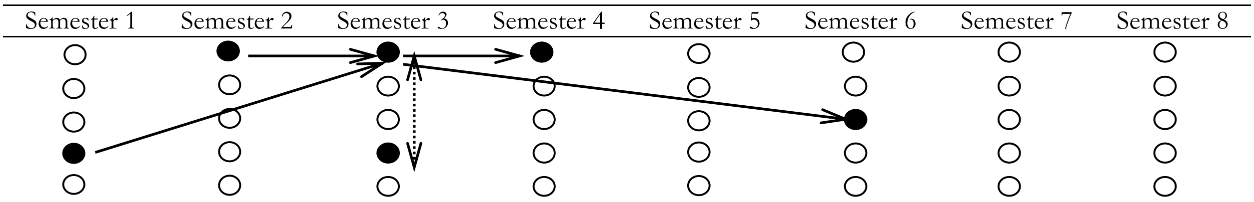
Chain Index (CI)

The course relaxation index (*RI*) does not indicate or quantify the contribution of a certain course to the overall stiffness of a curriculum or study plan. In most curriculums, some of the courses stand in long in-

Table 1. Logical Connection Strength (*CS*) values

Connection Scenario	*CS* Value
A connection between a course standing as a pre-requisite and a subsequent course directly in the next semester	1.0
A floating (standing alone) course that is not connected with any previous, current or subsequent courses in the curriculum or a connection between courses occurring after or before three semesters or more	0
A course connected to other courses in the same semester as co-requisites	0.5

Table 2. A hypothetical example of relaxation index (RI) calculation with the node at the first course in Semester 3 (Circles represent courses, solid arrows represent pre-requisites and post-requisites, and dashed two-directional arrows represent co-requisites)



tandem semester-to-semester chains of pre-and-post-requisites. This phenomenon poses a serious obstacle for the students and may potentially delay the completion of degree requirements if a student fails one of these courses occurring in long in-tandem chains.

In general, a course that acts as a pre-requisite for another course in the next semester and has only one pre-requisite directly in the previous semester is occurring in an in-tandem semester-to-semester chain length of 2. The in-tandem semester-to-semester chains of length of 2 are already taken into consideration in the aforementioned course relaxation index (*RI*). However, when the in-tandem semester-to-semester chain length becomes three or more, the chain length needs to be taken into account (Darwish, 2011). The chain index (*CI*) for a certain chain involving a certain course is logically defined logically by the following expression:

$$CI = 1 - \frac{Chain\ Length - 2}{NS - 2} = \frac{NS - Chain\ Length}{NS - 2} \tag{3}$$

Where *NS* is the number of semesters in the study plan. In case if a pre-requisite chain extends over all semesters in the study plan, which is unlikely to occur, the *CI* value would be zero. On the other hand, the value of *CI* would be 1 for a chain length of 2.

Net Relaxation Index (NRI)

Using the relaxation index (*RI*) and the chain index (*CI*), the net course relaxation index (*NRI*) for stressed courses occurring in long in-tandem semester-to-semester chains is computed as follows:

$$NRI = RI \times \prod_{k=1}^{k=NCh} CI_k \tag{4}$$

Where CI_k is the index of chain "*k*" for the stressed course under consideration, *NCh* is the number of chains involving the course, and the symbol $\prod$ signifies multiplication. However, in this study, the multiplication term is assumed to be dominated by the longest chain and hence only one term, corresponding to the longest chain, has been used in *NRI* computations.

Net Semester Relaxation Index (SRI)

The net semester relaxation index (*SRI*) for a certain semester in the study plan is simply the average of relaxation indices for all the courses occurring in that semester as shown below:

$$SRI = \frac{\sum_{k=1}^{NCS} (NRI)_k}{NCS} \tag{5}$$

Where *NCS* represents the total number of courses in semester under consideration.

Overall Curriculum Relaxation Index (CRI)

The overall curriculum relaxation index (*CRI*) is computed as the average of all courses' relaxation indices over the whole study plan. The equation is shown below:

$$CRI = \frac{\sum_{k=1}^{NS} (NRI)_k \times (SRI)_k}{NC} \tag{6}$$

Where *NC* represents the total number of courses in the overall study plan.

RESULTS & DISCUSSION

In this section, we discuss and analyze the implication of the above quantitative measures to the study engineering curricula at four of the leading universities in the UAE that is the American University of Sharjah (AUS), the University of Sharjah (UOS), United Arab Emirates University (UAEU), and the Petroleum Institute (PI). Table 3 provides a summary of the selected engineering curricula from each university, including the total number of courses and the total number of credit hours.

Using the study plans of the selected engineering programs, the net course relaxation index (*NRI*) for each course was calculated using Eqs. (1-4). The semester relaxation index (*SRI*) was calculated using Eq. (5) and finally, Eq. (6) was used to predict the overall curriculum relaxation index (*CRI*). As an example, Table 4 shows the study plan for the Chemical Engineering Program at the American University of Sharjah (Darwish, 2011). Each course in the study plan was considered as a node and the *NRI* for each course was determined as shown in parentheses in Table 4. Similar tables were generated to calculate the relaxation indices for the engineering curricula mentioned in Table 3.

In a healthy structured study plan, it is expected that semesters relaxation index improves (increases) steadily from the first semester onwards. However, this trend was not observed in any study plan offered by the four universities. In case of AUS, Figure 1 depicts a very low value of *SRI* in semester 4 of the chemical engineering program. It is, therefore, advisable to relax some of the pre-requisites in this semester. The courses in the civil engineering curriculum at AUS were found to be stressed in semesters 3 and 4 (second year). A special consideration is required to relax the pre-requisites in the mechanical engineering program at AUS that exhibited low *SRI* values in both the second and the third year of the study plan. The overall curriculum relaxation index (*CRI*) for the civil, chemical, and mechanical engineering programs at AUS were computed to be 82.0%, 70.0%, and 70.0%, respectively.

Figure 2 shows the *SRI* values for the engineering curricula at UOS. The electrical and electronics engineering curriculum at UOS exhibit extremely low values of *SRI* in the second year of the study plan. The mechanical engineering program, on the other hand, showed low *SRI* values in the second, third, and the fourth semester. The civil & environmental engineering program at UOS was found to be highly stressed by pre-requisites in the fourth and fifth semester. The overall curriculum relaxation index (*CRI*) for the civil & environmental, electrical & electronics, and mechanical engineering programs at UOS were computed to be 79.4%, 79.3%, and 81.1%, respectively. Compared to AUS, the engineering curricula at UOS were found to be slightly more relaxed.

Table 3. Summary of selected engineering curricula from universities in the UAE

University	Program/Major	Number of Semesters	Number of Courses	Credit Hours	Reference
The American University of Sharjah (AUS)	Civil Engineering	8	50	140	(AUS, 2015)
	Chemical Engineering	8	51	140	(AUS, 2015)
	Mechanical Engineering	8	51	140	(AUS, 2015)
The University of Sharjah (UOS)	Civil & Environmental Engineering	8	50	135	(UOS, 2015a)
	Electrical & Electronics Engineering	8	55	138	(UOS, 2015b)
	Mechanical Engineering	8	50	132	(UOS, 2015c)
The Petroleum Institute (PI)	Electrical Engineering	8	40	131	(PI, 2014a)
	Chemical Engineering	8	40	132	(PI, 2014b)
	Mechanical Engineering	8	44	135	(PI, 2014c)
United Arab Emirates University (UAEU)	Chemical Engineering	10	49	147	(UAEU, 2014a)
	Civil & Environmental Engineering	10	46	147	(UAEU, 2014b)
	Mechanical Engineering	10	50	147	(UAEU, 2014c)

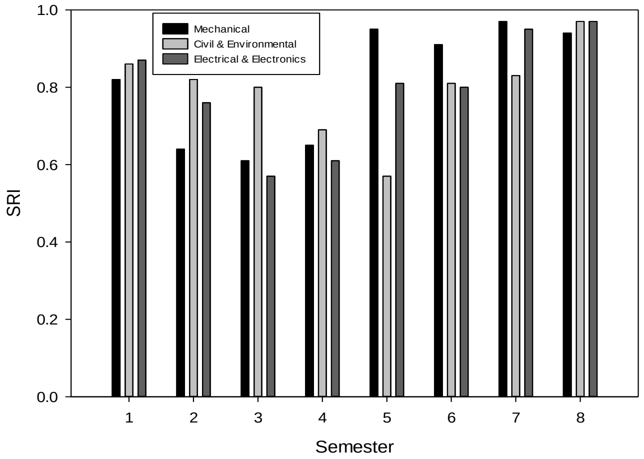


Figure 2. Relaxation index for each semester in the study plan for the Electrical & Electronics, Civil & Environmental, & Mechanical Engineering at the University of Sharjah (UOS)

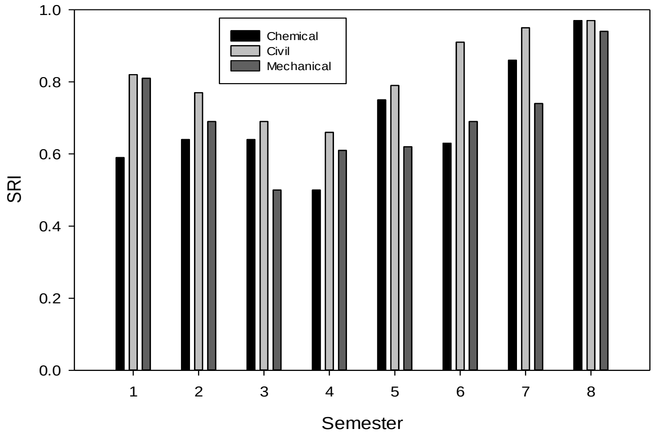


Figure 1. Relaxation index for each semester in the study plan for the Chemical, Civil, & Mechanical Engineering at the American University of Sharjah (AUS)

Table 4. The study plan for the Chemical Engineering Department at the American University of Sharjah with pre-requisites (solid arrows), co-requisites (dashed two-directional arrows), course relaxation indices (numbers in parentheses), and semester relaxation indices (numbers is the last row) (Darwish, 2011)

	Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
	CHM 101 (0.80)	FRE XXX (1.0)	MTH 205 (0.14)	CHE 206 (0.08)	ENG 207 (0.93)	CHE 304 (0.25)	CHE 421 (0.96)	CHE 452 (1.00)
WRI 001	WRI 101 (0.50)	WRI 102 (0.60)	HSS XXX (1.0)	CHE 215 (0.19)	HUM XXX (1.0)	CHE 321 (0.67)	CHE 432 (0.57)	MJE XXX (1.00)
MTH 001	MTH 103 (0.13)	MTH 104 (0.07)	CHE 205 (0.38)	CHE 240 (0.39)	CHE 305 (0.25)	CHE 332 (0.92)	CHE 451 (0.71)	MJE XXX (1.00)
PHY 001	PHY 101 (0.50)	PHY 102 (0.80)	CHE 230 (0.93)	CHM 216 (0.50)	**CHE 307 (0.14)**	**CHE 342 (0.42)**	CHE 490 (0.79)	CHE 491 (0.83)
	NGN 110 (1.0)	NGN 111 (0.70)	CHM 102 (0.79)	CHM 217 (1.0)	CHE 329 (0.79)	CHM 331 (0.5)	MJE XXX (1.00)	FRE XXX (1.00)
			CHM 215 (0.64)	MTH 221 (0.83)	ELE 225 (1.0)	CHE 397 (1.00)	ARA XXX (1.00)	HSS XXX (1.00)
			MTH 203 (0.48)		CHE 350 (0.86)		HSS XXX (1.00)	
			ENG 204 (0.79)		HSS XXX (1.0)			
SRI	0.59	0.64	0.64	0.50	0.75	0.63	0.86	0.97

The *SRI* values for the selected engineering curricula at PI are shown in Figure 3. All the curricula at PI were found to be highly stressed throughout semesters 2 to 6. Much of these pre-requisite stresses were particularly focused in the second year and in the later part of the first year of the study plans. The overall curriculum relaxation index (*CRI*) for the chemical, electrical, and mechanical engineering programs at PI were found to be 62.3%, 74.8%, and 75.5%, respectively.

The mechanical engineering program at UAEU showed a steady increase in *SRI* values from the first semester onwards with low *SRI* value only in the fourth semester (Figure 4). Similarly, a steady increase in *SRI* values was also observed for the civil & environmental engineering program. However, the eight semester has a zero *SRI* value since the only course in this semester, Industrial Training (CIVL 495), acts a pre-requisite for other courses in the subsequent (ninth) semester. Similar case was observed for the chemical engineering program at UAEU. The eight semester, corresponding to Industrial Training (CHME 495), has a zero *SRI* value. In addition, the courses in the second and fourth semesters were found to be stressed. The overall curriculum relaxation index (*CRI*) for the civil & environmental, mechanical, and chemical engineering programs at UAEU were found to be 91.4%, 86.7%, and 79.1%, respectively.

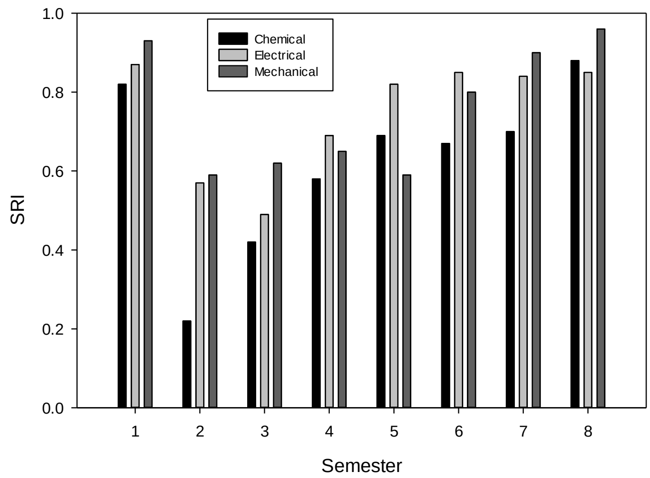


Figure 3. Relaxation index for each semester in the study plan for the Chemical, Electrical, & Mechanical Engineering at the Petroleum Institute (PI)

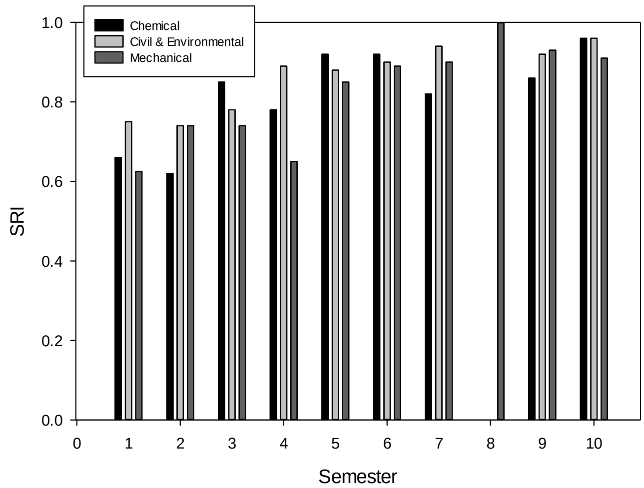


Figure 4. Relaxation index for each semester in the study plan for the Chemical, Civil & Environmental, & Mechanical Engineering at the United Arab Emirates University (UAEU)

In short, the chemical engineering study plan at PI is the least flexible while the civil & environmental study plan at UAEU is the most flexible among all the study plans considered in this study. Each selected university is suggested to give immediate attendance towards relaxing the strong pre-and-co-requisite ties connecting the stressed courses (*NRI* < 0.5) listed in Table 5. These courses are, in fact, the bottlenecks for students' progression from one semester to another. In order to facilitate smooth progression of students from one semester to another, strong ties of the pre-and-co-requisite must be avoided and the *SRI* should improve (increase) steadily from the first semester onwards. Relaxation of strong pre-and-co-requisite ties requires expertise in each curricula. Although relaxation of strong pre-and-co-requisite ties will enhance the curriculum flexibility, important curriculum objectives such as efficient achievement of course and program learning outcomes may be compromised. For the courses listed in Table 5, any changes or adjustments in the pre-and-co-requisites must be made taking into account the course and program learning outcomes.

The proposed metric has been successfully applied to different engineering curricula in the United Arab Emirates. Although curriculum flexibility can be quantified, the metric has certain limitations. The connection strength (*CS*) value is based on logic and can assume any value between zero and one. For the same curriculum, this may result in different *SRI* and *CRI* values depending on the *CS* values assumed by the metric user. In addition, only pre-and-co-requisite ties have been considered as a factor affecting smooth student progression. Other factors such as course content and level of difficulty have not been embedded within the metric. Furthermore, the metric is only applicable to American-based curricula and may have

Table 5. Courses that require relaxation of strong pre-and-co-requisite ties in the studied engineering curricula (*NRI* < 0.5)

University	Program/Major	Stressed Course Title (Course Code)
The American University of Sharjah (AUS)	Civil Engineering	Calculus II (MTH 104), Statics (CVE 220), Fluid Mechanics (CVE 240), Mechanics of Materials (CVE 223), Geotechnical Engineering Principles (CVE 331)
	Chemical Engineering	Calculus I (MTH 103), Calculus II (MTH 104), Differential Equations (MTH 2015), Principles of Chemical Engineering I (CHE 205), Calculus III (MTH 203), Principles of Chemical Engineering II (CHE 206), Fluid Flow (CHE 215), Computer Methods in Chemical Engineering (CHE 240), Chemical Engineering Thermodynamics I (CHE 303), Heat Transfer (CHE 307), Chemical Engineering Thermodynamics II (CHE 304), Separation Processes (CHE 342)
	Mechanical Engineering	Calculus II (MTH 104), Physics II (PHY 102), Thermodynamics I (MCE 241), Statics (MCE 220), Electric Circuits and Devices (ELE 225), Dynamics (MCE 222), Mechanics of Materials (MCE 223), Fluid Mechanics (MCE 240), Engineering Measurements (MCE 311), Mechanical Design I (MCE 321), Computer Applications in Mechanical Engineering II (MCE 326L), Control Systems (MCE 410)
The University of Sharjah (UOS)	Civil & Environmental Engineering	Statics (0401201), Surveying (0401222), Mechanics of Materials (0401202), Dynamics (0401243), Fluid Mechanics (0401343), Geotechnical Engineering (0401351), Transportation Engineering (0401321), Reinforced Concrete Design 1 (0401314), Senior Design Project 1 (0401498)
	Electrical & Electronics Engineering	Physics II Lab (1430118), Digital Logic Design (0403201), Circuit Analysis I (0402202), Circuit Analysis I Lab (0402203), Signals and Systems (0402240)
	Mechanical Engineering	Statics (0401201), Calculus II for Eng. (1440161), Differential Equations for Eng. (1440261), Dynamics (0401243), Kinematics (0408220), Mechanics of Materials (0401202)
The Petroleum Institute (PI)	Electrical Engineering	Calculus II (MATH 161), Communication II (COMM 151), Electric Circuits I (ELEG 205), Differential Equations (MATH 261)
	Chemical Engineering	Chemistry II (CHEM 102), Physics I: Mechanics (PHYS 191), Calculus II (MATH 161), Communication II (COMM 151), Physics II: Electromagnetism (PHYS 241), Calculus II (MATH 212), Engineering Practices I (STPS 201), Principles of Chemical Engineering (CHEG 200), Differential Equations (MATH 261), Fluid Mechanics (CHEG 301), Designed Experimentation (CHEG 331), Heat Transfer (CHEG 361), Mass Transfer (CHEG 351), Design Project I (CHEG 490)
	Mechanical Engineering	Physics I: Mechanics (PHYS 191), Communication II (COMM 151), Engineering Statics (MEEG 201), Strategies for Team Based Eng. Problem Solving I (STPS 201), Differential Equations (MATH 261), Fluid Mechanics (MEEG 354), Engineering MATLAB (MEEG 221), Systems Dynamics & Control (MEEG 384)
United Arab Emirates University (UAEU)	Chemical Engineering	English Language (2100), Mathematics (3100), Calculus I for Engineering (MATH 1110), Physics I for Engineering (PHYS 1110), General Chemistry I (CHEM 111), Calculus II for Engineering (MATH 1120), Physical Chemistry I (CHEM 251), General Chemistry II (CHEM 112), Industrial Training (CHME 495)
	Civil & Environmental Engineering	Mathematics (3100), Calculus I for Engineering (MATH 1110), Calculus II for Engineering (MATH 1120), Industrial Training (CIVL 495)
	Mechanical Engineering	English Language (2100), Mathematics (3100), Calculus I for Engineering (MATH 1110), Physics I for Engineering (PHYS 1110), Calculus II for Engineering (MATH 1120), Statics (GENG 240), Mechanics of Materials (GENG 305)

limited applications for curricula based on yearly modules or qualifications such as those in most universities in the United Kingdom.

CONCLUSION

In this study, a quantitative index (relaxation index, *RI*) was used to reflect the degree of interconnectivity between courses in engineering curricula at the American University of Sharjah, the University of Sharjah, United Arab Emirates University (UAEU), and the Petroleum Institute. The values of *RI* were used to determine the overall semester and the overall study plan relaxation index. The chemical engineering curriculum at PI was found to be the least flexible while the civil & environmental curriculum at UAEU was found to be the most flexible among all the study plans considered in this study. It is strongly recommended to relax some of the strong ties of pre-requisites prevailing in the semesters with low values of *SRI* for each study plan.

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A study of students' achievement in algebra: Considering the effect of gender and types of schools

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ABSTRACT

Algebra is a branch of mathematics that deals with symbols and also the rules for manipulating those symbols, which are used to represent numbers and quantities in mathematical formulae and equations. It is needed and used in our everyday lives. The purpose of this study was to examine students' performance in algebra related to gender and types of schools.The research sample consisted of 317 students (135 boys and 182 girls) from three types of schools in Malaysia ie; national schools, Islamic-religious schools and boarding schools. Data were collected through an instrument known as the Algebra Achievement Test (AAT), and were then analyzed quantitatively using a two-way ANOVA test. Research findings showed that there were statistically significant main effects for gender and types of schools towards students' achievement in algebra. However, no interactional effects were found between gender and types of schools that could influence the results obtained.It is concluded that gender and types of schools do effect students' achievement in algebra.

Keywords

earth, rock,
middle school (ages 11-14),
vocabulary,
discourse

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INTRODUCTION

Algebra has always been one of the main subjects in mathematics the world over. This fact is concurred by 65 countries around the world which participated in the Programme for International Student Assessment (PISA), including Malaysia. This is probably due to the fact that algebra is the door to the extension of complex arithmetic articulations, and a progression leap from concrete to abstract concepts in learning mathematics (Skouras 2014). The placement of algebra, as subject of study in mathematics within a school's syllabus, might be different as some countries might offer it in an integrated syllabus, while others might employ it as unified body strands within their mathematics curriculum, like algebra, arithmetic and geometry.

In Malaysia, algebra is integrated into the mathematics syllabus via chapters. It is first introduced to students at the primary school level, and the syllabus progresses into the more comprehensive and advanced stages at the secondary school level. To ensure proficiency in mathematics, students generally have to sit for mathematics classes for at least four to five periods a week. However, regardless of the fairly well thought of syllabus, the Malaysian average mathematics output, as found by the Trends in International Mathematics and Science Study (TIMSS), was still lags far behind other Asian nations such as Japan, Hong Kong, Korea and also Singapore (Mullis et al. 2004). Furthermore, Malaysia has never performed well in mathematics in PISA, and is known as one of the worst performers in 2012, when it ranked below 50, together with countries such as Columbia, Peru and Albania. In addition, the analysis of TIMSS-2007 showed that Malaysia scored the lowest, with only 24% and 2.1 points, which ranks far below the International Average Score, set at 34% with 0.3 points, and has to

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settle for the last place, even below Thailand and Indonesia. In the Malaysian context, the condition gets worse, as there is a lack of data for researchers to further investigate the factors affecting mathematics achievement, especially at the secondary school level (Lim & Saleh 2002; Lim 2003).

This has led to more interest in many parties to investigate students' achievement in mathematics, as the subject has always been correlated with greater chance of employment, better wages and higher on-the-job productivity (Geary & Hamson 2000). With that reason, it is significantly important to recognize the factors that affect students' mathematics achievement, in order to make good progression and prediction for the future, relating to mathematical decisions. However, this paper will focus only on equity, in relation to two dimensions: gender and types of schools.

LITERATURE REVIEW

Each student is unique in terms of acquiring knowledge in learning. In terms of results, student performance may be poor, not necessarily because they do not have the skills, but more to the fact that they have not been able to optimize their skills (Bandura 1977). Some said that it is important to measure student achievement in mathematics, as their achievement in high school can have a direct and influential effect on their mathematics performance at the tertiary level (Ismail & Awang 2007). Furthermore, according to the Centre for the Study of Testing, Evaluation, and Educational Policy (SCTEEP) at Boston College, a test in mathematics is also used to describe students' overall achievement in a non-hierarchical way. Hence, assembling a student's overall results may just be the right kick start needed to assess and elicit a wider range of skills from students, in algebra.

As previously mentioned, it has been found that Malaysian students' achievement, particularly in the subject of mathematics, is on a heavy decline. Analysis showed that in TIMSS-1999, Malaysia was placed 10th out of 38 participating countries, with an average score of 519 points. It was the highest place that Malaysia has ever reached, as it then flunked to 16th out of 46 countries in TIMMS-2003, with an average score of 508 points, before falling down further to 20th place out of 50 participating countries in TIMSS-2007, with a score of 474 points. The downward spiral got worse in TIMSS-2011, when Malaysia stumbled to 26th place with 440 points, and continued its decline in PISA 2012, when it ranked 57th place in mathematics, out of 74 countries which took part in the examination.

It is an irrefutable fact now that Malaysian students are facing a problem in mathematics proficiency, and much can be said about their achievement in mathematics, compared to their counterparts worldwide, and even within neighboring countries. The disparity is obvious, when comparison is made with Singapore, our closest neighbor. Ismail and Awang (2008) found that more than 50 percent of students in Singapore scored higher than the average score of 603 in TIMSS-2003, compared to only 10 per cent of student in Malaysia who managed to do so in the same exam. By comparing the contents tested in TIMSS, such as geometry, measurement, fractions and algebra, researchers found out that Singaporean students have always scored significantly higher than Malaysian students, regardless their gender. Results also showed that girls have always outperformed boys in every area tested, with girls averaging a mean of 53.0, while boys generally hover around the mean of 47.0.

Based on the secondary data of TIMSS-1999, Ismail and Awang (2007) found that there was a significant difference between Malaysian boys' and girls' performance. The research shows that out of 5,577 Malaysian students (girls - 55.2 per cent, boys - 44.4 per cent) involved in TIMSS-1999, aging on average of around 14.4 years old, with a standard deviation of 0.36, girls outperformed boys in mathematics. Four years later, using the same procedures, Ismail and Awang (2011) once again found out that girls (M = 479.88, SD=75.94) still scored better than boys (M = 468.27, SD = 80.37) in their test. The results were analyzed using data from TIMSS-2007, which involved 4,466 students from 150 schools in Malaysia. This finding was consistent with the results obtained from TIMSS-2007 participating countries such as Serbia, Macedonia, Armenia, Moldova, Singapore, Philippines, Cyprus, Jordan and Bahrain (Ismail & Awang 2008; Mullis et al. 2008) This pattern continuously shows that girls consistently score higher than boys in mathematics in a stable manner, most everywhere around the globe.

Likewise, in the context of students' perceptions towards the mathematics classroom environment and mathematics achievement, Rajoo (2013) also found that girls performed better than boys. Using 445 students as his research sample, Rajoo (2013) found that girls tend to be more involved (more active and joyful) during mathematics lessons, as compared to boys. In relation to that, a study conducted by Abd. Razak, Thien and Darmawan (2014) found that there was also a significant relationship between teachers' gender and eighth grade student achievement in mathematics. In their research entitled "Relationship of Students and Classroom-level Variables with TIMSS 2011 Mathematics Achievement in Indonesia, Malaysia and Thailand", it was found that teachers' gender had a significant impact towards eighth grade student achievement in mathematics. Furthermore, when students' scores were correlated with teachers' gender, in the context of Malaysia, the results also showed that female teachers taught better than male teachers. However, unlike the previous studies, Ainuddin Dahlan et al. (2010) found that there was no significant difference between boys and girls achievements in four national schools in Kuala Lumpur, in terms of mathematics results in the Lower-Secondary National Examination (PMR).

Besides gender, studies also show that school types also effect students' achievement in mathematics (Lubienski & Lubienski 2006; Newhouse, 2006; Lubienski, Lubienski & Crane 2008; Esposito 2010). In the context of Malaysia, there are many different types of schools that have been set up to cater to the different needs and levels of students nationwide. Among the mainstream schools are national schools and national-type of schools (open to all residents, regardless of race, religious beliefs and gender), boarding schools (special school for selected high achievers), and Islamic religious schools (to Muslims who want to learn more about the teaching of Islam). It is a well known fact that boarding school students have always scored high marks in mathematics (particularly in the Malaysian standard examinations) compared to students from other schools (Nordin, et al. 2003). National and national-type rural schools students, on the other hand are generally left behind in terms mathematics achievement (Baharun et al. 2008). As elements in Islam are manifested through various aspects of the educational system (Joseph, 2008), the number of Islamic religious school is also on the rise. However, there is not much research done pertaining this type of school in the country. Although previous studies show that generally, students from religious schools perform better than those from public and private schools (Chubb & More 1990; Jeyness 2002, 2008; Nordin et al. 2003), this fact cannot yet be corroborated in Malaysia. There is lack of data available in relation to the comparison of students' academic achievement among different types of schools in Malaysian, as the issue is seen as 'sensitive' by the Malaysian Government (Joseph 2006, 2008).

RESEARCH QUESTION

What are the effects of gender and types of school on student's achievement in algebra?

a. Is there a significant main effect in terms of student's achievement in algebra between boys and girls?
b. Is there a significant main effect in terms of students' achievement in algebra amongst national schools, religious schools and boarding schools?
c. Is there a significant interaction effect between gender and types of schools in terms of students' achievement in algebra?

METHODOLOGY

This research adopted a survey research design to collect the required data. Purposive sampling technique has been used to select the schools and students. A total of 317 students (see Table 1) from 12 schools (four national schools, four Islamic religious schools and four boarding schools) with the similar status (government aided high performing school) were required to complete a test known as the Algebra Achievement Test (AAT) within 60 minutes, administered during the school hours. The AAT consisted of 30 multiple-choice questions (5 questions on knowledge, 17 questions on concept and 8 questions on higher order thinking skills). Data obtained were then analyzed quantitatively using Two-Way ANOVA analysis.

RESULTS

What are the effects of gender and types of schools on students' achievement in algebra?

Table 2 shows mean and standard deviation for gender in national schools, religious schools and boarding schools. Table 2 shows that the total mean score for boys (M = 20.73, SD = 4.82) is lower than the total mean

Table 1. Number of samples for national school, religious school and boarding school

Types of schools	Girl	Boy	Total
National school	67	39	106
Religious school	59	47	106
Boarding school	56	49	105
Total	*182*	*135*	*317*

score for girls (M = 22.02, SD = 4.22). Regardless of the types of schools, it can be concluded that girls (N = 182) outperform boys (N = 135) in algebra achievement in each school.

Table 3 shows results for Levene's test of equality of error variances. The significant (p) value is 0.03 (> 0.01), implies that the assumption for homogeneity of variance is not violated. Therefore, it can be said that each school and gender has equal variance in the mean scores of algebra.Table 4 shows results for the test of between-gender and types of schools effect.

Is there a significant main effect in terms of students' achievement in algebra between boys and girls?

Alternative hypothesis: There is a significant difference in terms of students' achievement in algebra between boys and girls.

Table 4 shows that there is a statistically significant main effect for gender [F (1,311) = 10.83, p = 0.00]. Although the effect size for gender is small, with eta squared value 0.03 (Cohen, 1988), it gives significant impact to a large sample (in this case, N = 317) (Pallant 2001). Thus, the alternative hypothesis cannot be rejected due to the p-values results (0.00 < 0.01). Hence, there is a significant main effect in terms of students' achievement in algebra between boys and girls.

Is there a significant main effect in terms of students' achievement in algebra amongst national schools, religious schools and boarding schools?

Alternative hypothesis: There is a significant difference in terms of students' achievement in algebra amongst national schools, religious school and boarding school.

Table 4 shows that there is a statistically significant main effect for schools [F (2, 311) = 25.57, p = 0.00]. The effect size for schools is considered as large (eta squared = 0.14). Thus, the alternative hypothesis cannot be rejected due to the p-values results (0.00 < 0.01). Hence, there is a significant main effect in terms of students' achievement in algebra amongst national schools, religious schools and boarding schools.

Table 2. Mean and standard deviation for gender in national schools, religious schools and boarding schools

Gender	School	Mean	Std. Deviation	N
Boy	National school	18.72	4.40	39
	Religious school	20.36	4.32	47
	Boarding school	22.67	4.95	49
	Total	20.73	4.82	135
Girl	National school	20.10	4.60	67
	Religious school	21.88	3.46	59
	Boarding school	24.46	3.17	56
	Total	22.02	4.22	182
Total	National school	19.59	4.56	106
	Religious school	21.21	3.92	106
	Boarding school	23.63	4.17	105
	Total	21.47	4.53	317

Table 3. Levene's Test of Equality of Error Variances

F	df1	df2	Sig (p)
2.52	5	311	.03

**The mean difference is significant at 0.01 level*

Table 4. Tests of between-gender and types of schools effect

Source	Types III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power
Corrected Model	1061.08	5	212.22	12.20	.00	.16	60.98	1.00
Intercept	140410.29	1	140410.29	8068.83	.00	.96	8068.83	1.00
Gender	188.47	1	188.47	10.83	.00	.03	10.83	.76
School	889.84	2	444.92	25.57	.00	.14	51.14	1.00
Gender * School	2.17	2	1.09	.06	.94	.00	.13	.01
Error	5411.89	311	17.40					
Total	152598.00	317						
Corrected Total	6472.97	316						

**The mean difference is significant at 0.01 level*

Is there a significant interaction effect between gender and types of schools in terms of students' achievement in algebra?

Alternative hypothesis: There is an interaction effect in terms of students' achievement in algebra between gender and types of schools.

Table 4 shows that there is no statistically significant interaction effect gender*schools [F (2, 311) = .06, p = 0.94]. The profile plot is shown in Figure 1. Therefore, the alternative hypothesis is rejected (p-value = 0.94 > 0.01). It can be concluded that there is no interaction effect in terms of students' achievement in algebra between gender and types of schools.

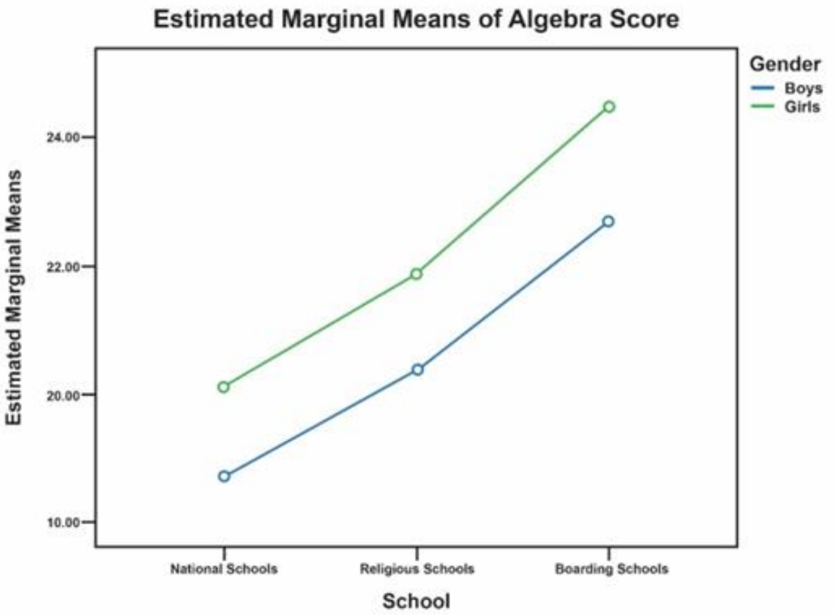

Figure 1. Profile plot for interaction effect between gender and types of schools

DISCUSSION

The results show that boarding schools' students (both boys and girls) outperform Islamic religious schools' and national schools' students in algebra achievement. Boarding schools' students obtain the highest mean score in the test administered, followed by Islamic religious schools' students and national schools' students. This may be due to the reason that boarding schools generally induct the best students and offer the most conducive learning environment, compared to the Islamic religious schools and national schools. Compared to national schools, the Islamic religious schools also take in better students and present a more conducive learning environment than national schools.

On the overall, it was found that girls (M = 22.02, SD = 4.22) outperform boys (M = 20.73, SD = 4.82) in terms of achievement in algebra, in all types of schools. Results obtained are parallel with the findings of Ismail and Awang (2007, 2012), Alkhateeb (2001), the US Department of Education, National Center for Education Statistic (2001), Mullis et al. (2008) and Rajoo (2013). However, the results are inconsistent with the findings of the American Institute of Research (2005), which found that boys perform better in things related to application problems.

The results are also in line with Freeman's (2005) findings, in which girls are found to develop greater confidence in their abilities to adopt with mathematical concepts and merge well with curriculum and assessment methods. Boys seem to understand the concepts of algebra faster than girls. However, girls often outperform boys as they tend to immerse themselves in practices and homeworks in order to polish their understanding about abstract concepts. Moreover, boys generally seem to view that doing homework as non-masculine-like (or feminine-like), and thus explains the reason why girls tend to become more superior in algebra, as compared to boys (Ainuddin Dahlan et al. 2010).

Moreover, this research finding is correlated with the research done by Ainuddin Dahlan et al. (2010), which found that even though boys have advantages in spatial and mathematical abilities, girls have always been consistent in adopting themselves with the curriculum. Besides, girls can most often tolerate lengthy lectures (traditional approach) given by the teacher, as the lower level of testosterones in their body makes it possible for them to adopt with this type of instruction, and as a result, excel more in mathematics. Compared to boys, girls also favor learning that involves solving problems related to real world situations, thus making them perform better in examinations.

Apart from that, girls also seem to outperform boys because the teacher-gender ratio is imbalanced at schools in Malaysia. Research by Abd. Razak, Thien and Darmawan (2014) showed that students who were taught by female teachers scored higher in eighth grade mathematics test, compared to those who were taught by male teachers. At the moment, according to the Educational Management Information System [EMIS] (2014), there is a huge gap between female teachers (127,030) and male teachers (55,385) at the secondary school level in Malaysia. This explains the reason for the learning style and curriculum at schools, which is more female-biased, where the interaction effect between teacher-gender and students' achievement has been found significant (Dee, 2006). On the contrary, the current findings also disagree with the research findings by Antecol, Eren and Ozbeklik (2012), which found that female teachers will lead to poorer results in mathematics among girls, not boys.

CONCLUSION AND IMPLICATION

This study has found that there is (i) a significant main effect in terms of students' achievement in algebra between boys and girls, (ii) a significant main effect in terms of students' achievement in algebra amongst national schools, religious schools and boarding schools, and (iii) no interaction effect in terms of students' achievement in algebra between gender and types of schools.

The findings of this study provide direct implications on the implementation of mathematics education in Malaysia, especially at the secondary level. There are several things that can be addressed in the context of student interest in mathematics. The Malaysian Ministry of Education (MOE) policy-makers should focus on the fair distribution of educational resources, particularly for the national and Islamic religious schools. Undoubtedly, teachers must also have the credibility and the responsibility to educate mathematics as equally fair as they can, without being biased towards any gender. And, ultimately, the school environment should also be cultivated towards fostering students' interest in mathematics more, as the benefits of this far outweigh other types of improvements for the students' future in the real world. Conclusively, the implications of this research could serve as referral data for the Malaysian Ministry of Education (MOE), to enable them to better monitor the gaps in terms of students' mathematics achievement amongst national schools, religious schools and boarding schools. Furthermore, educators should also be more creative and active in teaching mathematics, to ensure a more meaningful and fruitful participation of both boys and girls in learning process. Gender-imbalance in achievement at schools, if not remedied properly, may contribute to a wide gender gap, especially in terms of university enrollment, at the tertiary level.

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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

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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

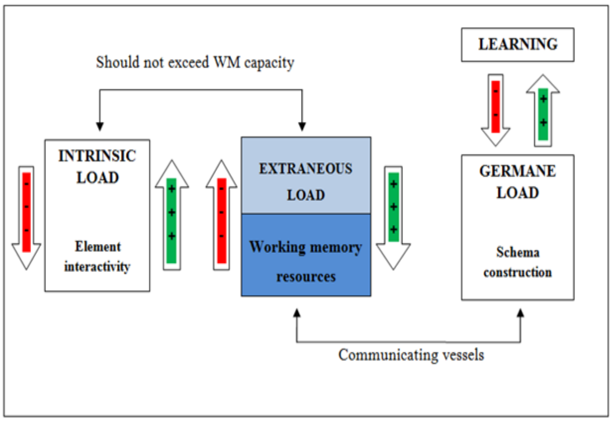


Figure 1. The influence of cognitive load on problem solving performance

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

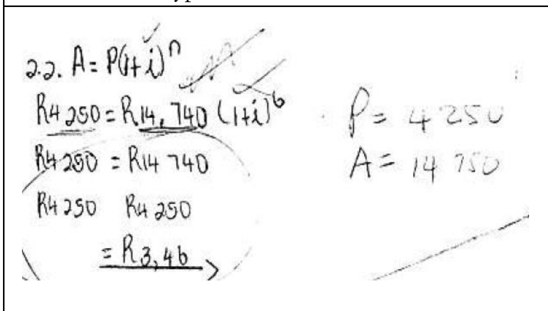
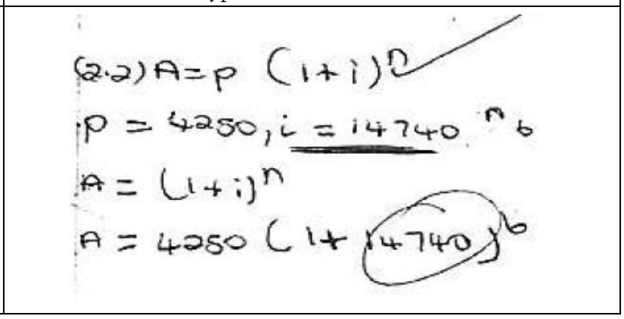
Table 2. Statistical results of the t-test analysis for the achievement test (FMAT)

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)

Type 1 of reverse error	Type 2 of reverse error
	

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
2.2 $A = P(1 + i \times n)$?? $A = R4\,250\,(1 + 14.74 \times 6)$ $A = R4250\,(1+0,1474)$ $A = R4250 \times 89,44$ $A = R380.120$

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.

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