

Enhancing Critical Thinking Dispositions in the Mathematics Classroom through a Flipped Learning Approach

Magda Kloppers* and Marieta Jansen van Vuuren

North West University, South Africa

KEYWORDS Habits of Mind. Attitudes. Inverted Approach. Inverted Learning. Inverted Delivery Model

ABSTRACT Unsatisfactory throughput rates as well as low mathematics averages for education students in higher education are a concern. A lack of critical thinking and critical thinking dispositions are possible contributing factors to poor performance. The aim of this ongoing research is to use flipped classroom learning as a teaching pedagogy and model that prepares students for their future careers. The aim of this flipped learning intervention is to enhance the critical thinking dispositions of mathematics students, to develop their understanding of mathematical concepts, to encourage responsibility for their understanding of knowledge and skills and to create opportunities for active learning through discovery and involvement with content. In addition, it explores the possibilities for students to become better problem solvers, with the aim of achieving increased throughput rates. The authors report on findings that flipped learning for the mathematics class seems to be a viable instructional methodology.

INTRODUCTION

The unsatisfactory throughput rates as well as low averages in mathematics are distressing. The public image of mathematics as being a difficult subject continues at university level. Students studying to become mathematics teachers who perform badly at university will soon stand in front of a class of learners, trying to explain difficult concepts. This is alarming, the more so since the education system is under suspicion. The Annual National Assessment results for Grade 9 in mathematics was 14 percent in 2013 (Anon. 2013), while Grade 12 learners and universities are on tenterhooks about the Grade 12 results. The National Curriculum Framework (NCF) (Department of Education, South Africa 2003), the Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education, South Africa 2011) and Lampert (2006) promote effective learning by mastering critical thinking skills and dispositions, *inter alia* by successfully identifying and solving problems and collecting, organising and evaluating information. These skills are important in a rapidly growing society and in an era of informa-

tion explosion, which has led to a state of information overload. The CAPS requires students to “develop the correct use of the language of mathematics; use mathematical processing skills to identify, investigate and solve problems creatively and critically and to communicate appropriately by using descriptions in words, graphs, symbols, tables and diagrams” (Department of Basic Education, South Africa 2011).

Although students choose mathematics as a major subject, they often do not prepare for contact sessions, choose not to do their homework activities (Aalbers et al. 2013) and perform poorly in tests and exams because they often give up hope when confronted with the challenge of applying theory (Star 2015). When students engage in doing their homework, they often experience frustration as they have nobody who can assist them with problems they are unable to solve and they have to wait until the next contact session for an opportunity to gain clarity on resolving the problem. In the traditional classroom there is often simply not enough time to revisit work done previously, and this results in the student possibly never receiving any clarity or help regarding the solution to the problem which he or she was working on.

University lecturers responsible for lecturing mathematics to education student teachers plan approaches through which to transfer not only knowledge to their students, but at the same time mastery of the necessary skills to enable them to transfer the knowledge successfully to

*Address for correspondence:
Magda Kloppers
North West University
School of Educational Sciences
P.O. Box 1174, Vanderbijlpark, 1900
South Africa
E-mail: Magda.Kloppers@nwu.ac.za

their learners when they start their careers as teachers. Teaching mathematics to large groups of students with varying mathematical abilities presents numerous challenges in any classroom. Lecturers have to plan using effective educational strategies for lecturing mathematics, but due to a number of co-producing factors, only have limited opportunities to ensure that all the students have full understanding of mathematical concepts, and that their understanding is enhanced.

One of the possible causes of poor performance is a lack of critical thinking and critical thinking dispositions that include truth seeking, perseverance, systematicity, problem-solving skills and an open mind. Wong and Chu (2014) point out that the traditional kind of classroom instruction benefits students who are motivated and engaged, but those who do not meet expectations because they are not required to think critically will not deeply comprehend the content. Interactive participation in class, problem-solving strategies and higher-order thinking skills should be encouraged so that students take responsibility for their own work and construct their own knowledge.

Thinking Dispositions

Thinking dispositions are defined as “personal attributes or habits of mind associated with one’s consistent internal motivation to engage in problems and make decisions using thinking” (Facione et al. 1997). Poor performance in mathematical problem tasks can be ascribed to students’ lack of the mathematical skills needed to solve problems or not knowing how to apply the mathematical skills that they do have to solving particular problems (Tuminaro and Redish n.d.). Paul and Elder (2008) argue that critical thinking is a prerequisite for critical thinking dispositions, which is supported by the view of Profetto-McGrath (2003) and Facione (2000, 2010, 2011) that critical thinking dispositions and attitudes are prerequisites for critical thinking as an important outcome of mathematics education.

Critical thinking dispositions in mathematics refer to the ability to search for alternative solutions to problems, effective problem-solving strategies, logical reasoning, a systematic approach and inquisitiveness. Biber et al. (2013) indicate that prospective mathematics teachers possess a low level of critical thinking dispositions.

Students should be able to apply past knowledge to new situations, be confident in their reasoning and persist (Royster et al. 1999; Van de Walle et al. 2010). To be open-minded implies that one’s own mistakes can be tolerated and respect for different approaches is shown (Facione 2011). Self-confidence reflects one’s confidence in one’s reasoning, while a person with a truth-seeking disposition asks courageous and probing questions, and thinks deeply about the reasons and evidence for and against decisions (Facione 2011).

The encouragement of critical thinking dispositions should be included in curricula, tasks and assessments to produce students who are able to think critically (Facione 2000; Ennis 2001; Halpern 2007). The classroom is the proper place to encourage critical thinking skills and dispositions and therefore educators should focus on the encouragement of critical thinking dispositions in their teaching (Lombard and Grosser 2008). Outdated teaching practices and teachers who lack the basic knowledge contribute to poor teaching standards (Makgato and Mji 2006). Classroom settings in which students structure their own knowledge (Staples 2007; Van de Walle et al. 2010) and in which they develop confidence in their skills to use mathematics (Heddens et al. 2009) should be created. Students should understand rather than memorise (MrcuI 2005; Van de Walle et al. 2010) and should be exposed to environments that encourage problem-solving skills and critical thinking skills and dispositions (Cuoco et al. 1996; Borko and Elliott 1999; Consiglio 2003; Department of Education, South Africa 2003; Maree et al. 2004; Pogrow 2004; Van de Walle et al. 2010).

Flipped Learning

Many teachers around the world have transformed their classroom practices by flipping the classroom since Bergman and Sams (2012a) began collaborating on ways to use technology to improve their face-to-face time with students when they started teaching at Woodland Park High School, Colorado. The approach that they initially called pre-broadcasting eventually became widely known as the flipped classroom (Bergman and Sams 2012b; Noonoo 2012). Many educators have attempted to implement this new model of instruction, seeking a positive impact on student success, with varying degrees of success.

The flipped learning model differs in that most of the direct teaching is delivered outside the usual face-to-face learning situation on the student learning platform or online learning space using video or other modes of delivery. Class time is then used for problem solving, collaborating and engaging with peers and evaluating their progress, instead of the traditional direct instruction delivery led by the lecturer. This gives the lecturers the opportunity to provide one-on-one assistance, to evaluate understanding and progress much better and to provide guidance and motivation. Lecturer-centred activities and classrooms become student-centred activities and environments (FLN 2014). Flipped learning research and results have shown in general that teachers who are flipping their classrooms report increased student success, improved student engagement, and better attitudes towards learning in general.

Results reported in the literature (Goodwin and Miller 2012) show the benefits of the flipped classroom, such as student engagement and increased student-teacher feedback. This is the environment that lecturers hope their students will recreate in their mathematics classrooms.

Flipped Learning as a Pedagogical Approach

As with the introduction of any new methodology, it is fundamental to have a clear and shared understanding of the meaning of the terminology. Due to the different interpretations in the literature and to counter some misunderstandings about the term, the governing board and key leaders of the Flipped Learning Network (FLN) have composed a formal definition of 'flipped learning'. It is defined as a "pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter".

The authors furthermore drew a clear distinction between a flipped classroom and flipped learning, emphasising that the two terms are not interchangeable. By implication, flipping a classroom does not necessarily lead to flipped learning (FLN 2014). Active engagement in flipped learning would involve lecturers implementing new and various methodologies, using more in-

class time for applied activities and more personalised instruction.

Although some educators may be of the opinion that using digital technologies or creating online concept videos to deliver subject content outside the class will result in less lecturing time, this is surely a misconception. The noticeable change is that the emphasis is placed on students to take responsibility for their own learning rather than on the instruction that is given during the contact session.

Jerry Overmyer, mathematics and science outreach coordinator for the Mathematics and Science Teaching Institute at the University of Northern Colorado is an advocate for the flipped classroom concept and is of the opinion that "the flipped model affords instructors the opportunity to "...be more engaged and personally understand the learning process of all their students" (Campus Technology 2012).

Flipped Learning as a Pedagogical Model

In a report developed by the FLN, Pearson's Centre Educator Effectiveness and experienced educators from George Mason University (Yarbro et al. 2014), four critical features or pillars of the flipped classroom were identified to guide educators through the concept of flipped classrooms. During a review and in the publication of the formal definition of flipped learning published by the FLN, 11 indicators were added to the four pillars for educators to use as self-assessment as guidance measures for integration and implementation in their classes. The four pillars of F-L-I-P™ refer to a Flexible Environment; Learning Culture; Intentional Content and Professional Educator to support student engagement.

Although various methodologies have been used for researching the flipped classroom (Brett 2012; Brame 2013; Mattis 2014), the researchers have based their approach on the four pillars of F-L-I-P™. With this pedagogical model as a reference, a flexible environment enables the educator to use the learning environment as a flexible space, allowing students to work independently but also in a face-to-face situation with fellow students and the lecturer. Moving instruction from a lecturer-centred to a more student-centred approach can lead to increased cognitive engagement and enhanced achievement of instructional goals and learning (Mattis

2014). Heddens et al. (2009), Staples (2007) as well as Van de Walle et al. (2010) claim that dispositions develop in classrooms where students have opportunities to reason and construct their own knowledge. In this way students are actively involved in knowledge construction and reasoning and a new *learning culture* is fostered in the flipped classroom. The third pillar of flipped learning has its foundation in assisting students to develop conceptual understanding as well as procedural fluency (FLN 2014). Educators have more time to facilitate discussion and are able to help students with activities and assigned problems, thus reinforcing the concepts during class time. Class time is used for student-centered, active learning strategies in teaching *intentional content*. The last pillar of flipped learning emphasises the complex role of the *professional educator* in the flipped classroom. Although the educator may take a less visible and prominent role in the flipped classroom (FLN 2014), the process of adopting this pedagogical model and its successful implementation requires dedication, reflective practice and willingness for transformation (FLN 2014) from both the educator and the student. The intentional selection and organising of stimuli for students (Fraser, 2006) enables them to distinguish between relevant and irrelevant information and can help them to persevere when solving problems (Fraser 2006; Costa and Kallick 2009).

The four pillars of F-L-I-P were used as a guideline and basis for the pedagogical approach to this research and was also used during the interpretation of the results and the students' qualitative feedback.

Objective

The objective of this paper was to determine the impact of the flipped classroom as a pedagogical approach to the critical thinking dispositions of second-year mathematics education students at a South African university.

Research Question

What is the impact of the flipped classroom as a pedagogical approach on the critical thinking dispositions of second-year mathematics education students at a South African university?

H_{A1} : The flipped classroom as a pedagogical approach has an impact on students' dispositions.

H_{o1} : The flipped classroom as a pedagogical approach does not have an impact on students' dispositions.

METHODOLOGY

Data Collection

For the purpose of this research, concept videos were made available online to second-year education students with mathematics as major. These concept videos which students had to watch prior to the contact session to perform certain tasks formed the key ingredient in the flipped approach. Concept videos were recorded in such a way that the students were required to watch sections which exposed them to explanations of new concepts and examples. During the video, they had to pause the video and solve given problems using pen and paper. For some of these problems the entire correct solution was given, and for some of the others only the correct answer was given. The rationale for giving only the correct answer and not the complete solution was to create an opportunity for discussion in the subsequent contact session. Another task which the students had to perform after completing a section was to create their own concept videos on any one of the topics in the section. The students performed these tasks as a group activity, which proved to encourage their critical thinking dispositions, among others perseverance, open-mindedness and confidence while interacting with each other. This also prepared them for their future careers.

A single-group, post-test-only design (McMillan and Schumacher 2006) was used for this study. The flipped classroom pedagogical approach and model was used as an intervention, after which critical thinking dispositions on interaction, homework, problem solving and performance were measured. Framed within a pragmatic research paradigm, a small-scale explanatory, mixed method research was employed to gather data. A quantitative survey research strategy with a self-developed, closed questionnaire on a four-point Lickert scale, ranging from strongly agree to strongly disagree, as the data-collection instrument was used to objectively determine the students' views on the flipped classroom. A number of questions were asked that related to the students' views on their interaction in class, homework and their preparation

for contact sessions, as well as their views on problem solving and their own performance. A maximum degree of objectivity was obtained by using quantitative numbers and statistics for the analysis of the students' opinions (McMillan and Schumacher 2006).

Following the quantitative data collection, a qualitative research strategy was employed by means of narratives. The results were used to better understand the students' views on the flipped classroom and to use these results to build a flipped learning mathematics environment for education students that could also benefit other fields of study where students need mathematics as a subject.

Sample

The target population for this study comprised all second-year education students with mathematics as a major at tertiary institutions. The sample for this study was all the second-year education students with mathematics as a major in the senior and FET phase ($n = 28$) at a South African tertiary institution.

Data Analysis

Questionnaires were analysed by dividing them into three categories. The first aim was to determine the students' perceptions of their interaction in class. The second aim dealt with the students' perceptions of homework and their preparation for contact sessions, and the last aim addressed the students' perceptions of their own performance and problem-solving skills. Qualitative data was used to better understand the students' views of the flipped learning environment.

Ethical Issues

Ethical aspects related to the research problem, objectives and research questions, data collection, data analysis and interpretation, and the reporting and dissemination of the research were taken into consideration (Creswell 2009). The research aim and the students' involvement in the research were discussed with the students, and a code was allocated to each student to ensure confidentiality and anonymity.

RESULTS

The guiding question that the researchers aimed to answer was: To what degree will the flipped

classroom in mathematics contribute to the encouragement of critical thinking dispositions through interaction, problem-solving strategies and the students' preparation in mathematics?

The flipped classroom was introduced to students. Concept videos were made and the students were requested to watch these videos and to look at notes and videos for which links were supplied in order to prepare for the next contact session. The contents of the videos were based on the outcomes of the module, and addressed introductory algebra for second-year mathematics education students. The students had to pause the videos at certain intervals to do calculations and practical exercises on the specific topics, after which the solution or part thereof was provided and discussed in the video. During the contact session time was spent on the discussion of difficult concepts, and more advanced problems were solved individually and in groups. The students were also encouraged to reflect on their problem solving.

Quantitative Data

Interaction

Interaction in class is important as students are exposed to other students' ideas and a variety of approaches in problem solving (Van de Walle et al. 2013). This implies that students need to be tolerant of different ways of doing things, be flexible in their thinking in order to see situations from different points of view and to think and communicate with clarity and precision. Conditions for respectful discourse can encourage understanding and create communities of practicing mathematicians (Forman et al. 1998). This is confirmed by 65 percent of the respondents, who strongly agreed that they preferred more in-class learning activities. 61 percent of the respondents found communicating with the lecturer in class valuable, while 74 percent of the respondents found communicating with peers in class on problem solving more helpful after having watched the concept videos as shown on Table 1. The quantitative data is supported by the narrative responses of the respondents. The flipped classroom furthermore also encouraged the students to take responsibility for their own learning.

It seems that the flipped classroom encourages students' habits of mind through interaction and classroom discussion.

Table 1: Respondents' responses on interaction

<i>Interaction</i>	<i>Strongly agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Strongly disagree</i>
I prefer more in-class learning activities	65	30	4	0
I found communicating/interaction with my lecturer in class valuable	61	35	0	4
After having watched the concept video, I found communicating with my peers in class on problem solving helpful	74	4	9	13

Homework and Preparation

Homework and preparation are normally considered to be a huge problem as students tend to copy each other's work. Persistence as a habit of mind is very important and students should be taught to use different approaches and to test their ideas (Clarke and Clarke 2003; Curran 2013; O'Daniel 2013). This is supported by 78 percent of the respondents, who strongly agreed that they understood concepts better after watching them on video before the contact session. Doing homework after watching a concept video was strongly agreed upon by 70 percent of the respondents. The flipped classroom is another approach that students can use to learn to persevere as this creates opportunities for them to relook at the same problem a few times until the concept is mastered. As soon as students can master a concept on their own, their

confidence in reasoning is also encouraged. The students also realised the importance of coming to class prepared as 61 percent of them strongly agreed that they put in more effort than before they were expected to use the flipped approach. This also allowed them to take responsibility, be prepared and gain value from problem solving in class instead of mastering concepts in contact sessions. Table 2 indicates how respondents benefited from homework and preparation.

Problem Solving

Problem solving should be an integral part of mathematics instruction as it encourages students to build upon their own thinking processes. This is supported by 45 percent of the respondents, who agreed that they could use different problem-solving strategies and skills as shown on Table 3.

Table 2: Respondents' responses on homework

<i>Homework</i>	<i>Strongly agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Strongly disagree</i>
I understand concepts better when I watch them before the contact session	78	13	0	9
It was easier to do homework after watching a concept video	70	17	9	4
I put in more effort than before my lecturer used the flipped approach	61	22	9	9

Table 3: Respondents' responses on problem solving and performance

<i>Problem solving and performance</i>	<i>Strongly agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Strongly disagree</i>
I understand Mathematics better with the flipped classroom approach	14	50	18	18
My marks in Mathematics improved	39	30	13	17
My knowledge of Mathematics improved	61	26	13	0
The flipped classroom supports my learning	65	17	0	17
I can now use different problem solving strategies and skills	45	32	18	5
I can successfully use higher order cognitive skills like evaluating, analyzing and synthesizing	43	43	13	0

Through reasoning and problem solving students' understanding improves and they are allowed to discard ideas and try out new possibilities. Students' confidence in reasoning can be encouraged through problem solving (Heddens et al. 2009; Facione 2011). When students are actively involved in problem solving and understanding of concepts, their confidence in reasoning can improve. The questionnaire data revealed that 50 percent of the respondents felt confident about their understanding of mathematics, while 61 percent were of the opinion that their knowledge of mathematics had improved. The respondents' data revealed that their knowledge of mathematics had improved and that the flipped classroom supported their learning and higher-order cognitive skills.

Qualitative Data

The students wrote narratives on their opinions of the flipped learning environment which were used to better understand their questionnaire responses. As preparation is of the utmost importance for performance in mathematics, the disposition of perseverance by better understanding and gaining confidence in reasoning is enhanced through the concept videos: "The flipped classroom is of much help during the contact session, because I have to prepare before class to see if I do understand the content". "The flipped classroom helps because you come to class knowing what you don't understand and the activity done therefore reinforces what you know or supplement, for you to do the homework". These comments emphasise truth seeking and the skills of problem solving in mathematics. Reflection on a task done is highlighted by the statement "And on my side it also gave me time to reflect on my lesson to see if what I did is relevant to what students must know". This furthermore stresses the importance of an open mind as a thinking disposition in mathematics.

The interpretation of the qualitative data according to the four pillars and with indicators of the possible encouragement of critical thinking dispositions is reflected on Table 4. The respondents' feedback is in the students' own words.

DISCUSSION

The findings of this research were guided by the research question and hypothesis. Al-

though the size of the sample was relatively small and a pre-test was not given (McMillan and Schumacher 2006), the authors found that the H_{01} hypothesis can be rejected and that the alternative hypothesis can be accepted.

The findings suggest that the education students in this pilot group who received flipped learning instruction demonstrated that they could successfully use higher-order thinking skills and problem-solving strategies. The respondents could also successfully use the flipped classroom approach to support their learning. They easily adapted to the approach and strategies as demonstrated by the mathematics lecturer. The in-class activities encouraged the development and application of critical thinking dispositions. The critical thinking disposition of confidence in reasoning was enhanced by the specific way in which concept videos were used and also allowed the respondents the opportunity to be better prepared for contact sessions. The concept videos also helped them to prepare for exams. In a study conducted by Triantafyllou et al. (2015) students similarly responded positively on the advantage of concept videos and the ability to pause and rewind the videos which reportedly lead to management of their cognitive load. This approach introduced the students to a new pedagogical model which had the added advantage of encouraging critical thinking dispositions. The students' confidence in reasoning and open-mindedness of views increased as they were more willing to share ideas and participate in problem-solving activities in class.

The results suggest that the education students in this pilot group who received flipped learning instruction could successfully use higher-order skills and problem-solving strategies, which are considered important in mathematics education. The in-class activities encouraged the development and application of critical thinking dispositions such as open-mindedness and perseverance. The data revealed that the students showed confidence in using mathematics to reason and to solve problems, which is an integral part of all mathematics learning. Students should be able to evaluate and justify their solutions and therefore the disposition of an open mind and perseverance are crucial. The students were seeking the truth as they reported that they re-watched the videos to gain a better understanding of concepts. They indi-

Table 4: The four pillars and critical thinking dispositions

<i>Four pillars of F-L-I-P™</i>	<i>Student feedback</i>	<i>Critical thinking dispositions</i>
F: Flexible environment	<i>All in all, the flipped classroom was fun, we got to do group work which brought us close and allowed us to share our thoughts with our peers, acquire the skill of working together and to learn from each other.</i>	*Sharing of ideas *Communicate with clarity and precision *Problem solving
L: Learning culture	<i>"... and in class that's where I have a chance to see if I did understand and as the lecture is introducing the concept to us that's where some of the things become clear and the knowledge build up from where I did find difficulties during my preparation. So this is of much benefit and I think is one of the greatest ideas the lecture have introduced to us to be more responsible on our studies and one thing that I do like about the flipped classroom is that even during contact session the lecture don't assume that we did understand the content on our own, but she tries to help where we ask for her assistance." "The flipped classroom is of much help during the contact session, because I have to prepare before class to see if I do understand the content" "The flipped classroom helps because you come to class knowing what you don't understand and the activity done therefore reinforces what you know or supplement, for you to do the homework." "I personally enjoyed the flipped classroom since to me doing more applications is much more profitable than to know a little about the content"</i>	*Truth seeking *Perseverance *Confidence in reasoning *Truth seeking
I: Intentional content	<i>"At first I thought to myself this just will be a waste of time but when I sat down and watched the videos to prepare for class I realized that watching a video is better than using a book." "I found the flipped classroom required us to do more work in terms of preparing for class – you were screwed if you didn't. It allowed us to know what we didn't understand when we went to class."</i>	Perseverance
P: Professional educator	<i>"... when I had questions I was able to bring them to the contact sessions and be answered, that is what I think helped us as students to understand MATE221 a whole lot better." "Presenting a lesson in the form of a video is much more interesting because if your students have the video they can go back to the parts which they did not understand." "And on my side it also gave me time to reflect on my lesson to see if what I did is relevant to what students must know."</i>	*Confidence in reasoning *Open-mindedness

cated that they had been exposed to skills equipping them as prospective educators to show tolerance and an open mind when learners' calculations might differ from theirs and when the lesson might move in different ways than anticipated depending on their students' interactions and responses when reasoning in the mathematics class.

The respondents could also successfully use the flipped classroom to support their learning. They easily adapted to the approach and strategies. The critical thinking disposition of confidence in reasoning was enhanced by the concept videos and also allowed the respondents the opportunity to be better prepared for

contact sessions and for the exams. This approach introduced the students to a new pedagogical model which had the added advantage of encouraging critical thinking dispositions. Students need dispositions that will enable them to persevere with more challenging problems, to take some responsibility for their own learning, to communicate their reasoning with clarity and precision and to show confidence in mastering mathematics.

As noted by Frydenberg (2012), an added advantage of teaching using this pedagogical method is that it models an experience that prepares students for their careers, in this case particularly their careers as educators.

CONCLUSION

The researchers acknowledge that no generalisations beyond the scope of the data can be made. However, the present study can serve as a point of departure for further studies to identify similarities and differences within other student populations in other contexts.

RECOMMENDATIONS

Even though the implementation of the model in this research project delivered positive results, it is not the intention of the authors to advocate replacing the lecturer or traditional textbook or study material with online videos. The intention is rather to encourage educators to create more opportunities for dynamic learning through discovery and involvement, instead of lecturing in and creating an environment in which the students are passive.

The tasks performed by students while watching concept videos could be expanded. They could, for example, be required to complete a short online test on the learning management system after having worked through the video. Concept videos could be enriched by using online tools which would allow questions to be added in the video and prevent the students from continuing until all the questions have been answered correctly.

LIMITATIONS

Although the findings of the research may still be relative, they have implications for teaching mathematics. This research was a small-scale study and restricted to one university and one subject area at tertiary level, and therefore the results cannot be generalised. A more extensive study could be undertaken to determine the impact of flipped learning on the critical thinking dispositions of education students taking mathematics as a subject.

REFERENCES

- Aalbers MW, Hommes J, Rethans J, Imbos T, Muijtjens AMM, Verwijnen MGM 2013. Why Should I Prepare? A Mixed Method Study Exploring the Motives of Medical Undergraduate Students to Prepare for Clinical Skills Training Sessions. *BMC Medical Education*, February 13: 27 From <<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3598397/>> (Retrieved on 18 June 2015).
- Anon 2013. ANA Results, released Friday, 6 December 2013, 15:06 From <<http://www.skillsportal.co.za/page/education/1637646-2013-ANA-results-released#Uqs6QNIW0g0>> (Retrieved on 2 October 2014).
- Bergman J, Sams A 2012a. *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Washington: ISTE.
- Bergman J, Sams A. 2012b. *Flipped Learning: Gateway to Student Engagement*. Washington: ISTE.
- Berrett D 2012. How 'Flipping The Classroom' Can Improve the Traditional Lecture. *The Chronicle of Higher Education*. From <<http://chronicle.com/article/How-Flipping-the-ClassRoom/130857/>> (Retrieved on 5 October 2014).
- Biber AC, Tuna A, Incikabi L 2013. An investigation of critical thinking dispositions of mathematics teacher candidates. *Educational Research*, 4(2): 109-117.
- Borko H, Elliott R 1999. Hands-on pedagogy versus hands-off accountability: Tensions between competing commitments for exemplary math teachers in Kentucky. *Phi Delta Kappan*, 80(5): 394-400.
- Brame C 2013. Flipping the Classroom. From <<http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom>> (Retrieved on 23 November 2014).
- Campus Technology 2012. *Technology Transforming Education: 4 Real-World Models of Success*. White Paper, Rosetta Stone. December. CA: Chatsworth.
- Clarke DM, Clarke BA 2003. Encouraging Perseverance in Elementary Mathematics: A Tale of Two Problems. *Teaching Children Mathematic*. From <http://blog.scs.sk.ca/sproat/view_media.pdf> (Retrieved on 20 November 2014).
- Consiglio V 2003. How do Students Learn Best? From <<http://www6.district125.k12.il.us/~vconsigl/teacherpage/ResearchPaper.pdf>> (Retrieved on 28 June 2011).
- Costa AL, Kallick B 2009. Toward a mindful language of learning. In: AL Costa, B Kallick (Eds.): *Learning and Leading with Habits of Mind. 16 Essential Characteristics for Success*. Victoria, Australia: Hawker Brownlow Education, pp. 117-134.
- Creswell JW 2009. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 3rd Edition. Los Angeles: Sage.
- Cuoco A, Goldenberg EP Mark J 1996. Habits of mind: an organizing principle of mathematics curricula. *Journal of Mathematical Behavior*, 15(4): 375-402.
- Curran B 2013. The Key of Unlocking Common Core Standards in Mathematics. From <<http://www.teachingchannel.org/blog/2013/03/26/ccss-math-perserve/>> (Retrieved on 22 January 2014).
- Department of Basic Education, South Africa 2011. *Curriculum and Assessment Policy Statement. Grades 10-12 Mathematics*. Cape Town: Government Printing Works.
- Department of Education, South Africa 2003. *National Curriculum Statement. Grades 10-12 Mathematics (General)*. Pretoria: Government Printer.
- Ennis RH 2001. Goals for a critical thinking curriculum and assessment. In: A Costa (Ed.): *Developing Minds*. 3rd Edition. Alexandria: VAASCA Publications, pp.44-46.
- Facione PA 2000. The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill. *Informal Logic*, 20(1): 61-84.
- Facione PA 2010. Critical Thinking: What It Is and Why It Counts, 2010 Update. Insight Assessment. From <http://www.insightassessment.com/pdf_files/what&why2006.pdf> (Retrieved on 15 November 2014).

- Facione PA 2011. *Think Critically*. Boston: Prentice Hall.
- Facione PA, Facione NC, Giancarlo CAF 1997. *Professional Judgment and the Disposition toward Critical Thinking*. CA: California Academic Press.
- Flipped Learning Network (FLN) 2014. The Four Pillars of F-L-I-P™ From <<http://flippedlearning.org/site/default.aspx?PageID=1>> (Retrieved on 7 November 2014).
- Forman EA, Larreamendy-Joerns J, Stein MK, Brown CA 1998. "You're Going to want to find out which and Prove It": Collective Argumentation in a Mathematics Classroom. *Learning and Instruction*, 8(6). From <<http://www.sciencedirect.com/science/article/pii/S0959475298000334>> (Retrieved on 12 December 2013).
- Fraser JDC 2006. Mediation of learning. In: MM Nieman, RB Monyai (Eds.): *The Educator as Mediator of Learning*. Pretoria: Van Schaik, pp. 1-21.
- Frydenberg M 2010. Flipping Turns Passive Listening to Active Learning. But It's Got to be Done Right. From <<http://www.bentley.edu/impact/articles/flipped-classroom#sthash.eg7jetD.dpuf>> (Retrieved 14 November 2014).
- Goodwin G, Miller K 2013. Evidence of flipped classrooms is still coming in. *Educational Leadership*, 70(6): 78-80.
- Halpern DF 2007. The nature and nurture of critical thinking. In: R Sternberg, HL Roediger, DF Halpern (Eds.): *Critical Thinking in Psychology*. Cambridge: Cambridge University Press, pp. 1-12.
- Heddens JW, Speer WR, Brahier DJ 2009. *Today's Mathematics: Concepts, Methods, and Classroom Activities*. NJ: Wiley, Hoboken.
- Lampert N 2006. Critical thinking dispositions as an outcome of art education. *Studies in Art Education*, 47(3): 215-228.
- Lombard K, Grosser M 2008. Critical thinking: are the ideals of OBE failing us or are we failing the ideals of OBE? *South African Journal of Education*, 28(4): 561-579.
- Makgato M, Mji A 2006. Factors associated with high school learners' poor performance: A spotlight on mathematics and physical science. *South African Journal of Education*, 26(2): 253-266.
- M-rcu I 2005. Critical thinking – applied to the methodology of teaching mathematics. *Educasia Mathematic*, 1(1): 57-66.
- Maree JG, Louw CJ, Millard S 2004. Die impak van tutoriale op die wiskundeprestasie van eerstejaarstudente. *Tydskrif vir Natuurwetenskap en Tegnologie*, 23(1): 25-34.
- Mattis KV 2014. Flipped Classroom Versus Traditional Textbook Instruction: Assessing Accuracy and Mental Effort at Different Levels of Mathematical Complexity. *Technology, Knowledge and Learning*. From <<http://link.springer.com/article/10.1007/s10758-014-9238-0/fulltext.html>> (Retrieved on 12 October 2014).
- McMillan JH, Schumacher S 2006. *Research in Education: Evidence-Based Inquiry*. 6th Edition. Boston: Allyn and Bacon.
- Noonoo S 2012. Flipped Learning Founders Set the Record Straight. From <<http://thejournal.com/articles/2012/06/20/flipped-learning-founders-q-and-a.aspx>> (Retrieved on 20 September 2014).
- O'Danie R 2013. Addressing Perseverance in Problem-Solving. From <<http://ctonline.org/addressing-perseverance-in-problem-solving/>> (Retrieved on 24 November 2014).
- Paul R, Elder L 2008. The Miniature Guide to Critical Thinking. Concepts and Tools. From <<http://vault.hanover.edu/~ahrens/CT.pdf>> (Retrieved on 15 June 2011).
- Pogrow S 2004. Supermath: An alternative approach to improving math performances in grades 4 through 9. *Phi Delta Kappan*, 86(4): 297-303.
- Profetto-McGrath J 2003. The relationship of critical thinking skills and critical thinking dispositions of baccalaureate nursing students. *Journal of Advanced Nursing*, 43(6): 569-577.
- Royster DC, Kim-Harris M, Schoeps N 1999. Dispositions of college mathematics students. *International Journal of Mathematical Education in Science and Technology*, 30(3): 317-333.
- Staples M 2007. Supporting Whole-Class Collaborative Inquiry in a Secondary Mathematics Classroom. Center for Research in Mathematics Education Publications, Paper 1. From <http://digitalcommons.uconn.edu/merg_docs/1> (Retrieved on 20 June 2011).
- Star JR 2015. When Not to Persevere Nuances Related to Perseverance in Mathematical Problem Solving. From <http://www.spencer.org/resources/content/4/3/4/documents/star_mip_0415.pdf> (Retrieved on 18 June 2015).
- Triantafyllou E, Timcenko O, Busk Kofoed L 2015. Student Behaviors and Perceptions in a Flipped Classroom: A Case in Undergraduate Mathematics. *Paper presented at the 43rd Annual SER Conference*, Orléans, France, June 29 to July 2, 2015.
- Tuminaro J, Redish EF n.d. Understanding Students' Poor Performance on Mathematical Problem Solving in Physics. From <http://www.physics.umd.edu/perg/papers/tuminaro/madison_proceedings.pdf> (Retrieved on 7 November 2014).
- Van de Walle JA, Karp KS, Bay-Williams FM 2010. *Elementary and Middle School Mathematics, Teaching Developmentally*. 7th Edition. New York: Allyn & Bacon.
- Van de Walle JA, Karp KS, Bay-Williams FM 2013. *Elementary and Middle School Mathematics, Teaching Developmentally*. 8th Edition. New York: Allyn & Bacon.
- Wong K, Chu DWK 2014. Is the flipped classroom model effective in the perspectives of students' perceptions and benefits? *Hybrid Learning. Theory and Practice, Lecture Notes in Computer Science*, 8595: 93-104.
- Yarbro Y, Arfstrom KM, McKnight K, McKnight P 2014. Extension of a Review of Flipped Learning. From <<http://flippedlearning.org/cms/lib07/VA01923112/Centricity/Domain/41/Extension/FLi-pped/Learning/LIt/Review/20June/2014.pdf>> (Retrieved on 20 November 2014).