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APPLICATION OF KHAN ACADEMY AS A WORKED-EXAMPLE VIDEO PODCAST TO SUPPLEMENT HIGH SCHOOL CALCULUS LEARNING

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ABSTRACT

One of the latest innovative approaches to supplementing mathematics classes is through using Khan Academy as a Worked-Example Video Podcast (WEVP). The video podcast includes step-by-step explanations of specific procedural problems found in mathematics. The impact of WEVP as a supplemental material has been studied sparingly, and there is none in high school calculus. The researchers examine the effect of Khan Academy WEVP as a supplement tool on the teaching of calculus to Grade 12 IBDP Math Standard Level students in a Chinese foreign school. Twenty-one students in the experimental group viewed a series of 20 video clips meant to teach key calculus ideas individually, while the remaining 21 students in the comparison group were given revision papers and received no other intervention. Pre-and posttests were used to collect data from both groups. The experimental group also received a self-report survey and open-ended questions. Results indicated that students who used WEVP did not do significantly better than the other group. However, most students enjoy using Khan Academy WEVP because it helps them understand the topic, pace their studies, prepare for tests, complete homework, and those who struggle with textbooks or lecturers. Thus, this study recommends including Khan Academy WEVP in high school calculus instruction for the aforementioned positive feedback. However, teachers should also consider the demotivating factors when using such video podcasts in their classes.

Keywords: Mathematics, Video Podcasts, Learning with Technology, Perception

INTRODUCTION

Online video education is a widely used method of delivering content to students (McGarr, 2009). Video podcasts, also known as vodcasts, webcasts, and video streaming (Treasure et al., 2010), are digital audio/video files distributed over the internet via personal computers or mobile devices (McGarr, 2009).Khan Academy (KA) is a popular educational video podcast that is heavily utilized by a large number of educators and students. Since it is a free online learning resource available to anyone with internet access, they can use it for self-regulation and lifelong learning. Similarly, it can be used in blended learning or flipped learning environments (Khan, 2020).The site features over 5000 online instructional videos in subjects like calculus, biology, physics, computer programming, and world history, among others (Khan, 2018).

The use of educational technology in mathematics has also been shown to have a positive impact on student achievement (Cheung & Slavin, 2013).In general, the benefits of Khan Academy podcasts in mathematics have been studied by many. According to Barrett (2018), the use of KA is associated with improved learning outcomes, and this is particularly true for students who are performing below grade level. Likewise, Parsons et al. (2018) found that math self-efficacy increased significantly, and math anxiety decreased significantly with the use of Khan Academy in mathematics. In the study by Murphy et al. (2014), students gained several advantages from using Khan Academy in their mathematics subject, such as increasing their academic engagement, self-regulation, self-efficacy, and math perception. Ruipérez-Valiente et al. (2015) found that the proper use of Khan Academy video podcasts helped students become more reflective and self-directed learners.Students can interact with and be interested in the math content,and it changes the way students and teachers work together because of its blended and personalized learning model (Light & Pierson 2014).

On the other hand, some studies revealed gaps and drawbacks in the use of Khan Academy in mathematics. Despite the widespread use of Khan Academy in classrooms, there is limited information about how students feel about using Khan Academy (Vidergor et al., 2020) and how it affects students' math performance (Kelly& Rutherford, 2017). In addition, McKain (2019) explains that while Khan Academy is widely used in schools globally, research on motivation to learn and eLearning is limited.Furthermore, the findings of Kelly et al.'s (2017) study indicated that using Khan Academy in mathematics did not statistically improve the test scores of the

students. Similarly, Kelly (2018) reported that the scores of ninth grade math students receiving only regular instruction or regular instruction along with Khan Academy for math remediation were not significantly different. According to the findings of Barman (2013), although Khan Academy videos were effective in teaching students about basic math concepts, they were less effective in teaching students about advanced concepts.

Meanwhile, video podcasts are classified as substitutional (Heilesen, 2010), creative (Armstrong et al., 2009), and supplementary (Copley, 2007) in education. The use of supplemental instruction has been shown to improve student performance in terms of grades, material retention, and motivation (Coletti et al., 2014).Reinforcement and deepening of learning usingsupplementary video podcasts (McGarr, 2009).A growing number of schools are using digital technologies to replace or supplement traditional teaching resources in mathematics classes (Geiger et al., 2015). Worked-Example Video Podcast (WEVP) is one of the applications of supplementary video podcasts (Yorganci, 2016) in mathematics, and it is designed to assist students in learning how to solve problems in specific fields (Kay, 2012) by featuring videos of instructors working through problems step by step (Kay & Kletskin, 2012). WEVP gained popularity because of the rise of Khan Academy, which has grown to be a significant video resource over the past decade.While studies on WEVP have started since 2006 (Heilesen, 2010), research about its impact on tertiary and secondary mathematics education is scarce (Kay, 2012). Most of the studies focus on the benefits of using written worked-examples (Sweller, 2006; Atikinson et al., 2000).

The worked-example approach helps students' cognitive loads be more manageable (Kester et al., 2006) or be reduced (Chen & Woolcott, 2019). By incorporating it into video podcasts, students gain an additional level of control over their cognitive load by having the ability to pause, rewind, and replay the explanations at any time and from any location. According to Kay and Edwards (2012), students find WEVP technology useful because it allows them to control their own learning pace and presents problems step-by-step.The use of WEVP as supplement material may be a promising approach for high school students struggling to understand the concepts and solve procedural-based problems in calculus. By integrating this technology into teaching calculus, students will be able to develop their ability to solve mathematical problems (Crippen & Earl, 2004), as well as develop positive attitudes towards the subject (Hill & Nelson, 2011; Kay& Edwards, 2012). However, students may encounter challenges and limitations in accessing this technology (Moss, O'Connor, & White, 2010).

The varying results of the use of Khan Academy in mathematics and the use of such tools as WEVP to supplement learning high school calculus provide opportunities to further explore it. Hence, this paper aimed to evaluate the effectiveness of Khan Academy as a WEVP supplemental tool to enhance high school students' learning in calculus. The research questions addressed were: (1) Is Khan Academy as WEVP effective in increasing the test performance of students in high school calculus subjects? and (2) What are the perceptions of students using the Khan Academy as WEVP?

MATERIALS AND METHODS

This study utilized a quasi-experimental matched-pairing design.Forty-two Grade 12 students enrolled in the International Baccalaureate (IB) Mathematics Standard Level course in a Chinese foreign school were matched-paired and were grouped into experimental and comparison groups. The students in the experimental group were given access to the worked-example video podcasts and the revision paper taken from the IB past examination papers. The students in the comparison group had revision paper but no access to the worked example video podcasts. Both groups have the same teacher, study time, textbook, course materials, and other academic resources. To ensure that they were comparable, a pretest was given to them prior to the groupings.

The current study used twenty (20) teacher-made video podcasts, considering the content, length of the video, schedule, and assessment of the course. The videos were specifically made to cover the topics in calculus listed in the IB Math Standard Level syllabus. The average length of the videos was approximately eight to ten (8–10) minutes and showed a problem solved by the teacher in a step-by-step manner, followed by another problem to be solved by the student. The researchers forwarded the video clips to the students' email accounts, Schoology accounts (www.schoology.com), and mobile devices. To ensure that the students viewed the clips, the researchers sent reminders through short message sending applications like WeChat (www.wechat.com) and text messages and informed their subject teacher.

Both groups were given pretest and posttest examinations with a maximum score of seventy (70), all taken from the IB Question

Bank. However, only the experimental group was given the self-reported questionnaire to determine their perception of the video podcasts. Such a questionnaire was a 5-point Likert scale consisting of statements indicating the advantages and disadvantages of using WEVP from the research of Kay and Edwards (2012). Another open-ended questionnaire was distributed to them to shed more light on the advantages and disadvantages of the said intervention.The mean and standard deviation were used to describe the test performance of the Grade 12 IB Mathematics StandardLevel students. A two-sample *t*-test for independent samples was utilized to determine if there was a significant difference in the performance of the comparison and experimental groups in the pretest and posttest. The *t*-test for the pretest was deemed necessary to determine if the comparison group had the same

performance as the experimental group before starting the program. Furthermore, mean and standard deviation were used in this study to describe students' perceptions of the benefits and drawbacks of using video podcasts. Meanwhile, content analysis was used to process the experimental group's answers to the open-ended questions.

RESULTS

The pretest results of both groups reported a "below expectations" level of knowledge and understanding about the calculus topics, as reflected in Table 1.They had very little knowledge of the concept being taught before the start of the program. Moreover, these results showed no significant statistical difference; hence, both the experimental and comparison groups are comparable in terms of prior knowledge about the calculus topics.

Table 1. Test Performance of the Grade 12 Students in Calculus Course (n=42)

Group	Test	Mean % (SD)	Description	Increase of Test Score (%)
Comparison	Pretest	18.10 (11.61)	Below Expectations	49.47
	Posttest	67.57 (17.50)	Meeting Expectations	
Experimental	Pretest	21.43 (11.12)	Below Expectations	49.95
	Posttest	71.38 (14.72)	Exceeding Expectations	

Scaling: 69 – 100   Exceeding Expectation
       46 – 68   Meeting Expectation
       32 – 45   Approaching Expectation
        0 – 31   Below Expectation

After one month of intervention, both groups had more than a 49% increase in their test scores. The posttest score of the experimental group exceeded expectations ($M = 71.38, SD = 14.72$), while the posttest scores of the comparison group met *expectations* ($M = 67.57, SD = 17.50$) (Table 1). However, using an alpha level

Of .05 and conducting an independent-sample *t*-test, the result indicated that the collected data on the posttests does not provide enough evidence to conclude that the performance of the students who used the WEVP (M = 71.38, SD = 14.72) is significantly different from the performance of the students who did not use the WEVP

(M = 67.57, SD = 17.50), with t (40) = -.950, p >.05 (Table 2). As a result, students who used the worked example video podcast achieved results that were comparable to those of students who did not use the video podcast.

Table 2. T-Test Result of the Grade 12 Students' Posttest in Calculus Course (n=42)

Group	Mean % (SD)	t-value	df	p-value
Comparison	67.57 (17.50)			
		-.950	40	.450
Experimental	71.38 (14.72)			

Even if the Khan Academy as WEVP did not significantly increase their test scores, the students who used it were optimistic about its learning benefits. Overall, the students believe that using it is *useful* to their learning (Table 3). Results further indicated that students like using the Khan Academy as WEVP because of its learning features like replaying when they cannot understand the discussion (M = 4.55, SD = 0.510) and controlling the pacing of discussion by stopping and rewinding the explanation when needed (M = 4.20, SD = 0.768). Students believed that the video podcast was *useful* for improving their test scores (M = 4.10, SD =.718), revising for the test (M = 4.05, SD =.686), and answering their homework (M = 3.90, SD =.718). Moreover, the students believe that the video clips are more *useful* than their textbook. They also suggested that teachers make podcasts for each topic available (M = 4.05, SD =.887).

Table 3: Students' Perceptions of the Benefits of Using Khan Academy as a WEVP

	Mean	SD	Description
Engagement			
The video podcasts are engaging and interesting.	3.84	.602	Useful
Learning Features			
I like the video podcasts because I can replay topics I don't understand.	4.55	.510	Very Useful
I like the video podcasts because I can pause and rewind the explanation when needed.	4.20	.768	Very Useful
The video podcasts help me to understand the problem clearly.	4.10	.641	Useful
I like the video podcasts because I can watch it anywhere and anytime.	4.05	.826	Useful
Support			
The video podcasts are helpful to improve my test score.	4.10	.718	Useful
The video podcasts help me to revise for the test.	4.05	.686	Useful
The video podcasts help me to answer my homework.	3.90	.718	Useful
Comparing to other method			
The video podcasts are better than using my textbook.	4.05	.759	Useful
Future Purpose			
The teacher should always provide podcast for each topic.	4.05	.887	Useful
Mean	**4.09**		

Scaling:
4.2 – 5.0	Very Useful
3.4 – 4.1	Useful
2.6 – 3.3	Somewhat Useful
1.8 – 2.5	Not Very Useful
1.0 – 1.7	Not At All Useful

To explore the quantitative results further, the researchers also collected qualitative data. Three themes emerged from the content analysis, including enhanced learning, getting support, and comparison with other materials and classroom discussions.

The students pointed out how the Khan Academy video clips helped them learn the course content. Most of the comments were consistent with the previous results in Table 3. The typical comments were:

> "I can easily understand the part which I am confused about."
> "It is actually understandable since some questions [in the videos were] similar to our worksheets."
> "The problems are well explained, and I enjoyed studying with those videos."
> "I learn more on how to answer the given problem."
> "The video helped me to learn because it was clear, explained well and showed each step."

A number of students (n = 9) viewed the WEVP as a good supplementary material because they were getting additional support when learning at home, replaying the clips, notetaking, or when students were hesitating to approach the teacher. Sample comments are:

> "The lessons I don't understand in class can be replayed at home."
> "It helped me to understand the topics by watching all the topics again and again."
> "The video podcasts help in my revision than just having notes."

> "I can pause the video while finishing my notetaking."
> "I am always afraid to ask our teacher for help. The video will give me the help I need."

Several students (n = 8) compared the use of WEVP to other educational materials and classroom learning. Some students (n = 4) felt that learning with a textbook alone does not offer learning experiences like WEVP. There were some students (n = 4) who believed that they learned better using WEVP than in the classroom. Here are some representative comments:

> "The textbook does not offer engaging and motivating presentation like this."
> "The video podcast shows the process of solving problems and it's easy to follow than just reading my textbook."
> "I can learn the lesson without my classmates annoying noise"
> "Whenever I missed some explanation, I can replay the video. In the classroom, I can't make my teacher repeat what he said."

Students were also asked about the demotivating factors of using WEVP. Overall, the students encountered simple challenges in using WEVP. The absence of face-to-face instruction (M = 3.30, SD = 1.34), being too busy to watch the video (M = 2.90, SD =.0718), and the availability of revision paper as an alternative material (M = 2.85, SD = 0.875) were the most demotivating factors that students encountered. Other problems encountered were *negligible* and the students were able to work around them.

Table 4. Students' Perceptions Toward the Disadvantages of Using Khan Academy asWEVP

	Mean	SD	Description
Engagement			
I am too busy to watch the video podcasts.	2.90	.718	Somewhat Difficult
I find the video podcasts boring.	1.90	.718	Negligible
Technical Problems			
The file size is too big to download.	1.90	.912	Negligible
It takes time to download the video using my mobile device.	1.80	1.01	Negligible
I don't own a mobile device to watch the podcasts	1.15	.366	Easy to Use
Learning Features			
I don't like the video podcasts because I can't ask questions immediately to clarify some part of the explanation.	3.30	1.34	Somewhat Difficult
The video podcasts are too repetitive of the classroom lecture.	2.20	.894	Negligible
The video podcasts are irrelevant from the topics we discussed in the classroom.	1.45	.510	Easy to Use
Comparing to other method			
I like working with revision paper than with the video podcast.	2.85	.875	Somewhat Difficult
I prefer actual video of lecture than worked example podcast.	2.20	.894	Negligible
Mean	**2.165**		

Sca*ling:*

4.2 – 5.0	Very Difficult
3.4 – 4.1	Difficult
2.6 – 3.3	SomewhatDifficult
1.8 – 2.5	Negligible
1.0 – 1.7	Easy to Use

The open-ended question yielded 22 comments from the students about the demotivating factors of using Khan Academy as well as WEVP as supplementary materials. From the content analysis, several themes emerged, including technical problems, the absence of immediate feedback, and the existence of other supplementary materials.

Based on the comments, some students (n = 6) reported that they encountered technical difficulties in downloading due to China's internet restrictions. Sample comments

"*Whenever the connections were interrupted, I must start downloading the video again. It is so annoying*"

"*There are times I cannot login to my account in Schoology*"

"*The file is too big [to be downloaded] from Schoology.*"

Several students (n = 7) felt the importance of getting immediate feedback on the explanations they did not understand when watching the video clips. Here are the sample comments:

"There are parts [in the video] I don't understand. It would be better if we can ask question immediately, like in the classroom"

"I can't really ask questions when watching the video."

"I hope we could ask question if I don't get what the teacher is saying in the video."

Other students (n = 5) stated that they preferred working with the revision paper to using WEVP, particularly when they already understood the lessons.Some others (n = 3) are asking to upload the actual video of the classroom lecture instead of only the WEVP. Sample comments:

"I don't need to watch the video podcast in some topics. The revision paper is already enough."

"The revision paper helped me more to practice solving the problems than the video podcast when I already know the lesson."

"I want a recorded lecture be uploaded in Schoology."

"The teacher should also post the video of his lecture so I can focus on the lesson and do my notes at home"

DISCUSSION

The results of this study are consistent with the studies of Baker et al. (2010), Copley (2007), Lazari (2009), Kelly et al. (2017), and Kelly (2018). The test scores of the students did not increase significantly as compared to their non-viewing peers. Although their test scores did not significantly differ from their non-viewing peers, the students had a positive attitude towards their learning experiences. This agrees with the study of Copley (2007), Crippen et al. (2004), Kay and Edwards (2012), Parsons et al. (2018), Murphy et al. (2014), and Ruipérez-Valiente et al. (2015)

that using Khan Academy video podcasts enable students to develop academic success in problem solving and self-sufficiency. Survey data and content analysis show that students were able to understand the concepts as explained in the video. The step-by-step explanations and the flexibility that the WEVP gave the students lessened the cognitive load. Students were able to direct the pace of learning and were able to watch the video anytime and anywhere. Moreover, the ability to pause and rewind is found to be useful in notetaking.

On the other hand, the results contradict the findings of the previous research for middle schools conducted by Kay and Edwards (2012) and for tertiary education by Crippen and Earl (2004) and Alpay and Gulati (2010). The conflicting results of this study could be attributed to the revision paper given to the students. The previous research did not use other supplementary material other than the video podcasts to improve students' test scores. Questions in the revision paper were patterned after those in the IB question bank, which made the students familiar with the IB Math type of examination.While there were several benefits to using WEVP in learning high school calculus, students encountered demotivating factors. Students are having difficulty using the video clips as supplemental material when some of the concepts in the video are unclear. Students were not able to ask or clarify immediately, unlike having the teacher present in the classroom. This was also confirmed by the content analysis of the qualitative data. Moreover, because of the many academic requirements and coursework, students perceive watching the video as an extra requirement. Some students like working with the revision papers rather than watching it first in the video and then answering the revision papers. Those who

performed well in the class found it redundant to watch the video clips instead of immediately working with the problems in the revision papers. When students are already familiar with the concepts, they do not find watching the video clips to be useful.

Based on the content analysis, another demotivating factor of using WEVP involves interrupted internet connections. Students reported having problems downloading and logging in to their Schoology accounts. As an alternative, a teacher may produce video clips in the shorter version to have a smaller file size. Also, there are some who want to record the actual lecture for notetaking.

CONCLUSION

Using Khan Academy as a Worked-Example Video Podcast did not improve the academic performance of the students in Calculus relative to their non-viewing peers. However, the Grade 12 students could still benefit from using WEVP. The majority of the students appreciated being able to direct the pace of learning and were positive about the learning benefits for their homework, concept reviews, missed classes, and test preparation. Also, students struggling with using textbooks or listening to teachers benefited from WEVP. The demotivating factors of using WEVP were technical problems, busy schedules of students, repetitive classroom lessons, inability to clarify concepts taught in the video, and availability of revision papers. Thus, this paper suggests integrating WEVP into teaching high school calculus for the benefits mentioned above. However, math teachers should be aware of the things that will make students less excited about using WEVP as a supplement.

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