Journal of Asian Vocational Education and Training
Vol. 7, pp. 74-83, 2014

ISSN 2005-0550

An Investigation on the GSP Implementation in the Teaching of Mathematics at a Malaysian Technical School

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ABSTRACT

Mathematics has long been one of the most feared subjects among students. As such, educators have been constantly looking into different approaches to continue improving the delivery of this subject. This quasi-experimental study seeks to investigate the effectiveness of Geometers' Sketchpad (GSP) - a dynamic geometrical software, in the teaching and learning of Mathematics among Form Five technical school students. The study was conducted on 56 students which were divided into a control group and an experimental group. The control group received conventional teaching method while the experimental group was taught based on a GSP module designed to solve Trigonometric Functions for the duration of 8 weeks. The findings from this study have indicated that the use of GSP in the teaching of Mathematics has a positive effect on students' Mathematics achievement and GSP has helped the students to better retain the knowledge taught. In addition, through the survey conducted, the students in the experimental class and their teacher have demonstrated positive attitudes, interests and enthusiasm in this new learning approach. Some recommendations for policy and practice have been put forward.

Keywords: Geometer' Sketchpad (GSP), Technology in Mathematics Education, 21st Century Skills, Technical School, Malaysia

INTRODUCTION

Technology in Education

Modernization in society has moved rapidly thus making information and communication technology (ICT) essential in everyone's list. In education field, professionals from majority of the countries in the world realize that ICT could be one of the most important media to improve the standard of education. The use of technology is cited to be essential in teaching and learning Mathematics (Ittigson & Zewe, 2003). It improves the teaching process as well as enhances students' understanding of basic concepts by promoting collaboration and sharing of knowledge among students. In addition, the integration of technology in education could promote higher order thinking skills and better problem solving strategies which are in line with the recommendations by the National Council of Teachers of Mathematics (NCTM).

Geometer's Sketchpad (GSP) is a dynamic Mathematical software that uses exploratory approach in Mathematics. It is a computer software system for creating, exploring, and analyzing a wide range of Mathematics concepts in the field of algebra, geometry, trigonometry, and calculus (Geometer's Sketchpad Reference Manual, 2001). It has been one of the tools used to support the teaching and learning of many technical subjects especially Mathematics, Physics and Engineering in educational institutions. In Malaysia, the tool has been selected by the Ministry of Education as an official teaching tool for technical subjects in 2003. In the early days of GSP in Malaysia's education landscape, teachers were sent for training and materials were provided to ensure successful implementation. To date, the software is still maintained as a teaching tool in many schools and

universities. GSP has been selected as the technology tool in this study to take advantage of the respondents' familiarity about the tool and the availability of the software in schools.

The ICT initiatives in Malaysian educational environment were prompted by the PPSMI (Teaching and Learning of Science and Mathematics in English). However, the reversion of the PPSMI policy in 2012 has raised some concerns about its continuity and the ministry's willingness to support the policy. Acknowledging the importance of ICT in today's education, the ministry has continued to support the use of ICT in the efforts to enhance teaching and learning. This has been further emphasized through the Malaysian Education Blueprint (2013-2025), where one of the identified goals is to leverage ICT to scale up quality learning in Malaysia. The utilization of GSP as a teaching tool is very relevant to the blueprint's action plans where the use of ICT is to be maximized in order to support self-paced learning as well as to cater for more customized learning. This is also in line with the goals of the 21st century paradigm where the exposure to the ICT skills is of great importance.

Mathematics is chosen in this study as it has always been among the pre-requisites for the many technical courses. It is critical that students demonstrate a strong aptitude in this subject in order to progress to a higher level of education. Another aspect considered in this study was the institution in which this research was to be conducted. The researcher has selected a secondary technical school (with students of age between 16 to 17 years) to conduct this study, as this is a technical school where students will receive extensive technical training. As high as 70% of the students will join higher learning institutions taking up courses in technical fields hence it is important that they master the required skills.

STATEMENT OF THE PROBLEM

Mathematics being one of the critical subjects offered in schools has always received the attention from the stakeholders in education where very high expectations have been put to see students performing at their best for this particular subject. Teachers have been looking for varied approaches to continue improving the teaching and learning of Mathematics in school in a hope to overcome students' apprehensiveness toward this subject. Though the use of ICT is said to be able to enhance the learning, poor delivery and application of tools may hinder the effectiveness of ICT in this process.

Other considerations that have triggered this research to be undertaken are the demands of the 21st century skills such as knowledge building, digital literacy, problem-solving, innovation, self-regulation, collaboration and communication (Trilling & Fadel, 2009; Rotherham & Willingham, 2010). The learning preferences of the 21st century learners which require teachers to diverge from the traditional methods of teaching and bring into the classroom new and innovative approaches by incorporating technology.

Although research suggests that the use of digital tools such as GSP to facilitate the teaching process (Johari, Chan, Ramli & Ahmat, 2010; Meng & Sam, 2011; Eu, 2013) as well as to enhance students' understanding of Mathematics concept, there has been evident that indicates a degree of reluctance among teachers to fully explore and utilize GSP (Rovai & Childress, 2003; Teoh & Fong, 2005; Eu, 2013;). It is found that teachers are not fully utilizing the technology to enhance the teaching process (Chong, Sharaf & Jacob, 2005). Teachers may perceived that by using this tool, it would add more to their teaching load and the usage of GSP supersedes the efforts required to learn the tool (Effandi, Yusoff & Norazah, 2007).

The effectiveness of the integration of ICT tools such as GSP to support the teaching and learning is still debatable. However, to embark on an initiative which will call for an extensive development efforts in ensuring successful implementation of this tool, it is critical that the effectiveness of the identified tool (GSP) to be thoroughly tested, not only from the perspective of the students, but also from the point of views of the teachers. Only when it is clear that GSP can truly benefit the stakeholders, the next stage of implementation initiative can be invested on. In the view of this, a study on the effectiveness of GSP in the Mathematics teaching and learning is critical to be conducted.

PURPOSE AND OBJECTIVES OF THE STUDY

This study was designed to determine the effect of using GSP in the teaching Mathematics for the topic of Trigonometric Functions. The study explored the GSP's effect on students' achievement, the retention ability and attitude toward learning Mathematics using GSP. Specifically, the objectives of this study included:

1. To compare the Mathematics achievement between students who undergo the GSP integrated teaching and learning process and those with the conventional Mathematics instructions at a Technical School.
2. To compare the level of knowledge retention between students who undergo the GSP integrated teaching and learning process and those with the conventional Mathematics instructions at a Technical School.
3. To determine the students' attitude toward using GSP in learning Mathematics.

METHODOLOGY

In this study, a quasi-experimental design, specifically, non-equivalent groups' pre-test-post-test design was adopted because the participants were assigned to control and experimental groups based on cluster random sampling instead of a simple random sampling. This was due to the limitation imposed by the school system in Malaysia where the students were usually not allowed to be put in a new class (after the random assignment) because it may disrupt the school and the teachers' scheduling. The independent variable in this study was the GSP module and the dependent variable is the students' achievement in Mathematics (Trigonometric Functions) that was being tested. The selected demographic variables, i.e., gender, social economic status and performance in Mathematics are treated as moderator variables.

During the first week of the study, the Mathematics achievement pre-test was administered to a total of 56 students who to participated in the study. Based on the results of the pre-test, these students were divided into two groups, the control and experimental groups. From then on, the experimental and the control groups underwent different phases of the process until they merged again at the post-test phase. The experimental group underwent four phases in the process, namely: (1) Introduction to GSP - where the teacher conducted a few sessions on the basic commands and functions of GSP to familiarize the students with the software, (2) Teaching and learning of Trigonometric Functions - using Geometer's Sketchpad software, (3) Assessment - using a set of Trigonometric Functions test as the post-test, and (4) Questionnaire – to identify the attitude of the students toward learning mathematics using GSP. On the other hand, the control group underwent learning Trigonometric Functions using the 8-week conventional instructional followed by a post-test. Three set of tests, i.e., pre-test, post-test and retention-test were administered to all the 56 students from both groups in week 1, 8 and 10 respectively to examine the effectiveness of GSP in Mathematical skills attainment and the capability of GSP in increasing the retention of knowledge among students. The full mark attainable for each of these tests is 40.

Besides the Trigonometric Functions Achievement tests, a set of questionnaires adapted from The Mathematics and Technology Attitudes Scale (MTAS) were administered to the experimental group. The scale which was developed by Pierce, Stacey and Barkatsas (2007) was used in this study to measure the students' attitudes toward GSP. Some modifications have been made to the items by the first researcher to suit the objectives of the study. The instrument contained directions and 24 five-point Likert-scale items ranging from 1 to 5 denoting "Strongly Disagree" to "Strongly Agree". This questionnaire was aimed at examining the five affective variables which are likely to have an impact on learning Mathematics with technology such as GSP. The five affective variables are Behavioral Engagement (BE), Mathematics Confidence (MC), Affective Engagement (AE), Confidence in using Technology (TC), and Attitude to Use Technology to Learn Mathematics (MT).

The GSP Module

The experimental group was provided with "Exploring Trigonometric Functions with Geometers' Sketchpad" Module - a GSP integrated learning activities module developed by the researchers as a treatment. The control group was kept under control condition by providing conventional learning instructions. The theoretical underpinnings of the module are based on three main learning theories, i.e., behaviorism, constructivism and interactivity. The learning theory of constructivism and interactivity were the main consideration in the design of the module, although the behaviorist approach was also adopted to a lesser extent in some of the activities. In developing this module, the researchers have placed emphasis on Mathematical processes such as Mathematical thinking, reasoning, communication, connection and problem solving as a focus to improve the learning of Mathematics by the students. The illustrative properties of GSP allow visualizations and Mathematical representations which facilitates both the conceptualization of Mathematical ideas and concepts as well as in conjecturing and reasoning during the ensuing discourse. In addition, the module incorporates 21st century skills such as knowledge building and the use of ICT tool (GSP), problem-solving and innovations, collaboration and communication. It is expected that through the utilization of GSP in the learning activities, the students would have to a great extent, promoted extensive knowledge building, efficient collaboration and enjoyable learning experience which would have not been possible in the conventional setting of teaching and learning.

FINDINGS

The results derived from pre, post and retention tests were analyzed using SPSS package. Table 1 illustrated the results of the independent t-test comparing the pre-tests and post-tests of the control and the experimental groups.

Table 1: Independent t-test comparing the pre-test and post-test of the control and the experimental groups

GROUP	n	PRE-TEST		POST-TEST	
		Mean	Std Deviation	Mean	Std Deviation
Control	27	2.63	1.96	19.44	5.87
Experimental	29	2.62	1.78	29.79	5.04
Lavene's test					
F		0.386		0.023	
Sig		0.537		0.881	
t-test					
t		0.018		-7.097	
df		54		54	
Sig.(2-tailed)		0.986		0.000*	

* Significance at p = 0.05

Results of pre-tests for both groups concluded that homogeneity among the two groups of students at the beginning. The results of the post-tests revealed that there was a significant difference between the mean scores of the experimental group and the control group - in favor of the experimental group. It can be deduced that the higher mean score obtained by the experimental group is attributed to the utilization of GSP in the learning process and that GSP has brought about some positive contribution to the understanding of the subject matter by the students. The post-test results for both groups were further analyzed by looking at the mean scores for each question (Table 2).

Table 2: Independent t-test comparing post-test means of experimental and control groups according to question grouping

	Post-Test Question							
	Q1		Q2		Q3		Q4	
	Ctrl	Exp	Ctrl	Exp	Ctrl	Exp	Ctrl	Exp
n	27	29	27	29	27	29	27	29
Mean	1.28	2.81	3.26	3.71	8.15	10.79	1.69	2.12
Std Deviation	0.62	0.63	0.79	0.93	2.78	1.66	1.69	2.12
Lavene's test								
F	0.039		0.696		5.327		1.438	
Sig	0.845		0.408		0.025		0.236	
t-test								
t	-9.083		-1.934		-4.283		-4.365	
df	54		54		41.75		54	
Sig.(2-tailed)	0.000*		0.058		0.000*		0.000*	

* Significance at p = 0.05

The results in Table 2 showed that the mean scores of Question1, Question 3 and Question 4 for the experimental group were significantly higher than the mean scores of the control groups. However, the mean scores did not vary much in Question 2 between the two groups. Possible explanation could relate to the fact that Question 2 tested on concepts and skills that were taught by utilizing the least of visual learning and computer representations features inherent in GSP. Although a more thorough research has to be conducted to validate this claim, the findings nevertheless pointed to a positive and strong correlation between performance and visualizations. Thus, learning Mathematics through dynamic visualization feature integrated in GSP is an effective method for enhancing students' understanding.

Further, in order to investigate whether GSP has any positive contribution in facilitating the retention of knowledge learned by the students, a retention test was administered two weeks after the intervention was completed. Table 3 illustrates the results of the independent t-test comparing the post-test and retention-test of the control and the experimental groups.

Table 3: Descriptive statistics of students' achievement on post-test and retention-test for the experimental and the control groups

GROUP		POST	RETENTION	% Difference in Post-Retention
Control	Mean	19.44	9.52	
	n	27	27	51.05
	Std Deviation	5.87	5.30	
Experimental	Mean	29.79	19.17	
	n	29	29	36.65
	Std Deviation	5.04	4.83	

Results in Table 3 for retention test indicated that there was a significant difference between the mean scores in favor of the experimental group. The finding suggested that students using GSP as technology tools (experimental group) in their learning process retained Mathematics skills longer than did students who received traditional classroom instruction (control group). Further analysis found that the mean for the control group dropped by a bigger percentage (51.05%) in the retention-test from the post-test as compared to 35.65% in the case of experimental group. It can be concluded that the retention ability of knowledge and skills acquired by the students through GSP is better compared to the same ability in the control group receiving the conventional instruction. It is well known fact that affective domain (emotions, attitudes and beliefs) plays a central role in Mathematics learning. Table 4 depicted the results of the questionnaire given to the experimental group to examine the five affective variables which are likely to have an impact on learning Mathematics with GSP.

Table 4: Results of the Mathematics and Technology Attitudes Scale Test (MTAS)

	Subscale	Mean	SD
1	BE – Behavioral Engagement	4.11	0.36
2	MC – Mathematics Confidence	4.12	0.25
3	AE – Affective Engagement	4.66	0.25
4	TC – Confidence with Technology	4.04	0.59
5	MT – Attitude to Learning Mathematics with GSP	4.34	0.18

The results from Table 4 concluded that students possess positive attitudes in all the subscales of learning Mathematics with GSP. Relatively high scores in subscales AE and MT explained the eagerness and enjoyment derived from GSP environment class as compared to traditional instruction class. Students expressed their preference for GSP over the conventional method and agreed that GSP did have a positive contribution to learning Mathematics.

Table 5 illustrated the results of an independent samples t-test to determine whether there were significant differences between the combined mean scores for all the subscales and the selected demographic variables, i.e., gender, SES and Grade obtained in the Additional Mathematics Form 4 final examination.

Table 5: Independent t-test comparing between combined mean scores of subscale and selected demographic variables

	Selected Demography Variables					
	Gender		SES		Mathematics Exam Grade	
	Male	Female	< RM3000	≥ RM3000	A / B / C	D / E / G
n	18	11	11	18	20	9
Mean	4.25	4.30	4.21	4.30	4.24	4.32
Std Deviation	0.21	0.16	0.17	0.19	0.17	0.21
Lavene's test						
F	2.528		0.351		0.288	
Sig	0.124		0.559		0.596	
t-test						
t	-0.715		-1.255		-1.103	
df	27		27		27	
Sig.(2-tailed)	0.481*		0.220*		0.280*	

*p > 0.05

It is observed that there were no statistically significant differences between the means of the categories in Gender, SES and Grade. Possible explanations to this finding would be the fact that technology has become ubiquitous to everybody irrespective of their demographic background. While the finding suggested that gender perspective is not a factor in determining the attitudes toward GSP, the researchers have decided to investigate this perspective further due to popular perceptions in many studies that suggested otherwise. Table 6 illustrated the results of detail analysis of relationships of the five subscales by gender.

Table 6: Independent t-test comparing attitude subscales means of the students' gender

	BE		MC		AE		TC		MT	
	M	F	M	F	M	F	M	F	M	F
n	18	11	18	11	18	11	18	11	18	11
Mean	4.11	4.11	4.08	4.18	4.68	4.61	3.88	4.32	4.37	4.28
Std Deviation	0.40	0.30	0.28	0.16	0.25	0.23	0.63	0.42	0.16	0.20
Lavene's Test										
F	0.387		3.787		0.033		3.165		1.362	
Sig	0.539		0.062		0.857		0.087		0.253	
t-test										
t	-0.018		-1.045		0.708		-2.074		1.228	
df	27		27		27		27		27	
Sig.(2-tailed)	0.986		0.305		0.485		0.048*		0.230	

* Significant at p = 0.05

It was found that there were no significant differences across the attitude scales, with the exception to subscale Technology Confidence. Male students were found to be less confidence when compared to female students.

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

The results of this study have confirmed that GSP is effective in ensuring successful Mathematics learning as well as being instrumental in helping the learners retain the knowledge longer. Students demonstrated positive attitudes toward GSP as the main learning tool in Mathematics.

Effectiveness of GSP in the Attainment of Mathematical Skills

Based on the results obtained from the tests, it has been recognized that GSP is indeed a powerful and useful tool that can be used in the teachings of Mathematics at Technical School. The implication that can be deduced from this finding is the versatility learning and superiority of visualization offered by GSP in the teaching and learning of Trigonometric Function lead to a greater improvement compared to conventional teaching method. The findings also pointed out that where visualization was maximized in the teaching and learning activities with the help of GSP, the score gain was higher. Since the GSP based module used in this study has elements of 21st century learning skills embedded in the activities, the findings suggest that the GSP utilization in the teaching and learning of Mathematics can be effectively used to inculcate 21st century skills among students. Students have the opportunity to explore the use of ICT, involve intensively in knowledge building process, apply comprehensive problem solving and experience teamwork as part of their learning activities.

The implication of the findings has called for a stronger commitment and willingness from the teachers to incorporate this tool as part of the teaching and learning activities. It is also important that the teachers should aware and understand the expectation to keep abreast with the latest development of this tool in order to continue using it in an effective manner (Tileston, 2004). It also implies that since implementing GSP as a tool in the teaching and learning of Mathematics at school will involve incorporating ICT usage; a different set of attitude is expected from the students as the main users. It is expected that the students do not misuse this privilege. The time has come for the students to recognize the use of ICT is no longer for its fun factor but most importantly as an enabler to grasp the subject matter. For the school, the finding has implied that a new ICT policy has to be put in place to cater for a much heavier usage of technology. More tools may be required for the teaching and learning activities, the internet connection may need to be upgraded and basic technical training on relevant software and hardware used may be essential for the technical staff members to handle the requirements or issues that come with this new teaching tool.

The Mathematics curriculum will also have to be reviewed to accommodate for the new tool. Students may not benefit fully from the tool, if the syllabus does not call for its extensive application in the teaching. The main textbook used for the subject needs to include GSP based activities. Better commitment from both students and teachers to embrace this new teaching and learning approach can also be obtained by incorporating GSP elements as part of the formal assessment (Keng-Cheng & Peng-Yee, 2007). Both parties will be more motivated in taking up the tool knowing that learning it is crucial in order to be able to secure an excellent performance in the subject.

The Capability of GSP in Increasing the Retention of Mathematical Knowledge

The results of this study have also positively demonstrated GSP's ability to help students to retain the knowledge obtained in the teaching and learning process. Today's children respond positively to technology; they get more inspired and may retain more information if it comes to them through digital medium (Miller, 2009). Faced with the examination pressures and the expectations to deliver good results, teachers may want to explore GSP as a learning tool to teach the required syllabus and facilitate the retention of students' knowledge. The findings of this study on the capability of GSP to help students' retention of knowledge could be utilized to assist in the preparation of exam year students (Form Five) in particular. In addition, Mathematics is a subject well known for its hierarchical structure (Gagne, 1997), which refers to the need to master certain items of knowledge

and skills in order to progress to subsequent level of Mathematical knowledge. Thus, it implies that the use of GSP in the teaching and learning of Mathematics is pertinent in facilitating students to retain knowledge acquired and to be able to apply it when dealing with the advanced topics in the syllabus.

Students' Attitudes toward Learning Mathematics using GSP

The findings concluded that students possess positive attitudes toward most of the subscales of learning Mathematics with GSP. Relatively high scores were recorded in subscales AE and MT explained the eagerness and enjoyment derived from GSP environment class compared to traditional instruction class. Students expressed their preference for GSP over the traditional method and agreed that GSP did have a positive contribution to learning Mathematics.

It can be implied from the findings that teachers have the role to translate students' positive attitudes toward learning Mathematics using technology into better Mathematics learning. While most of today's students like technology, it does not automatically translate into better learning. It was suggested that teachers should provide the impetus by giving students responsibility for their own learning and by challenging students with advanced Mathematical problems that require deep thinking (Ullman, 2011).

In general, the findings from this study also showed that the students' attitudes to learning Mathematics with GSP are not associated with gender, social economic background or their Mathematical achievements. This implies that Mathematics teachers can plan about integrating GSP in a more comprehensive way as the students - irrespective of their gender, social economic status and Mathematics achievements - are receptive toward learning Mathematics with technology. The results also implied that the way technology is used in classroom depends largely on the teacher and hence school administrators should play a role to encourage the use of ICT among teachers to enhance the teaching and learning process.

Results also indicated that there is a significant difference in the attitudes of the students toward Confidence in using technology (TC) when grouped according to gender. Female students exhibited better attitudes toward confidence in using technology than the male students. This result contradicted the common finding that boys express greater confidence than girls regarding the use of technology (Pierce, Stacey & Barkatsas, 2007) therefore it warrants further investigation. However, it can be implied from this finding that, in planning technology based teaching instructions, teachers need to take into account the differences identified so as to ensure equality in learning experiences and knowledge acquisition regardless of the level of technology confidence possessed by the respective genders. Based on the findings and limitations of the study, some recommendations to address the identified implications are put forward:

1. Among the initiatives to promote a high level of awareness on the benefits and importance of GSP as a learning tool, thus securing teachers' commitment in using GSP are: sending teachers for formal trainings on GSP, inviting the product experts and external trainers who have extensive experience in teaching Mathematics using GSP for a knowledge sharing session and establishing a dedicated task force to develop contents for subject's delivery using GSP. Furthermore, the school administration may also consider teachers' efforts in learning and undertaking the new tool and applying it in their teaching and learning activities as part of the key performance indicators during the annual appraisal.
2. It is important that the school administrators who worked on ways to inculcate a more responsible culture in handling and appreciating the ICT elements to address the issues of potential misuse of ICT equipments among students. In addition to knowledge sharing sessions and continuous reminder to students, the school may also want to consider installing monitoring tools to curb inappropriate usage of the computer facilities. It is also hoped that through the new approach in teaching and the newly structured contents, the students appreciate GSP roles as the enabler for learning more than an entertainment tool.
3. While it is clear that limited resources will hinder the success of GSP integration in the Mathematics subject's delivery, not all schools can afford to make available the equipments. Thus, it is recommended that the schools with this limitation to implement the 'Bring-Your-Own-Device" approach, where students and teachers are encouraged to bring along and work on their personal machines. This approach has long been applied by education institutions and

schools and received very well by the students and teachers for being able to maintain the personalized experience if they use their own devices.

4. The development of the Higher Order Thinking Skills (HOTS) among students which has been emphasized in the Malaysia Education Development Plan (PPPM) 2013-2025 can be made possible through the implementation of GSP as using it to learn Mathematics calls for extensive problem solving and critical thinking. In addition, the use of GSP may provide a solution to the issue of protecting instructional time as highlighted in the Protection of Instructional Time (MMI) policy. Teachers can prepare for the teaching and learning activities to be undertaken by the students in the event of having to be absent to attend meetings or formal trainings. Students can then embark on self-learning and exploration and the school administration shall not worry about the unmet teaching and learning time as stipulated in the teachers' lesson plan.
5. Future research regarding the effectiveness of GSP should consider students from various education pathways such as religious schools, arts and sports schools, accelerated learning program for high-performing and gifted schools, Form 6, and matriculation. A comprehensive research taking into consideration students from different academic background would serve as a good complementary to the findings of this study which was conducted on technical school students. A further study to create a framework on GSP implementation that looks into a combination of different perspectives mainly from the users' attitudes toward the technology and the organizations' readiness in having the technology on board can also be conducted. This framework is to serve as a guideline for a successful implementation of GSP in schools. Another area of research relating to use of GSP in teaching and learning could be conducted to probe on other features of GSP apart from its visualization and exploration features. The extent to which GSP can contribute to the inculcation of 21st century skills such as knowledge building, digital literacy, problem-solving and innovation, self regulation, collaboration and communication could well be an interesting eye-opening research.

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