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Exploring Students' Cognitive Loads that Inhibits Total Participation in Mathematics

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Abstract— Total participation is an essential factor that promotes class mastery and empower students' motivation. It can be obtained by exploring the cognitive loads of the students when teachers develop activities for the class. Teachers in Mathematics find it quite difficult to obtain total participation from the students. This descriptive study determined the cognitive loads of the students that affects their active participation in Mathematics class. The respondents of the study were the Grade 9 public school teachers and the Grade 9 students at San Pedro Relocation Center National High School, a public secondary school in the Southern Luzon, Philippines. The respondents, chosen though stratified random sampling, were given a survey questionnaire. Data gathering was conducted during the third quarter of the academic year 2019–2020. Pearson product moment correlation and One-Way ANOVA were applied to analyze the statistical data. It was found that the regularity of the variables namely intrinsic load, germane load, extraneous load, context, design, power, and scalar fit are always observed by the respondents in their Mathematics class. However, these cognitive loads differ in terms of total participation. It was concluded that cognitive activation is the teaching strategy applicable in enhancing students' total participation and motivation, either extrinsic or intrinsic, in Mathematics learning.

Index Terms— *cognitive loads, extraneous load, germane load, intrinsic load, motivation, total participation, Mathematics instruction*

1 Introduction

PERFORMANCE comprises one of the highest parts in a regular educational system. It can be measured in various ways and one of which is the participation of the students during the actual class discussion. In this case, without active participation, students' performance may be incomplete, or it cannot truly be attained. A study by Clancy showed that the subject having most inactive students is in Mathematics, in comparison with other fields [2]. This urges the researchers to investigate the situation and determine ways in improving the participation of students in Mathematics learning. The study targets to explore various cognitive loads of the students to find ways in improving their participation in the study of Mathematics. This way, the most influencial cognitive load that would inhibit students' total participation will be identified.

As stated by Himmele and Himmele, Total Participation Techniques (TPTs) are teaching techniques that allow students to demonstrate, at the same time actively participate and manifest cognitive engagement in the topic being studied [7]. TPTs, as a strategy in Mathematics instruction, can be used in the exploration of various cognitive loads that promotes active participation. With the use of this technique, instructions will be more realistic in a way that learners will have the chance to demonstrate their prior skills and experiences.

Benn states Mathematics curriculum needs to be realistic to honor what the students bring into the classroom specifically their academic, personal, and work experiences [1]. Theoretically, it can be justified by social constructivist theory of learning. The basic premise of the theory is that for students to learn, they should participate in the community of practice where knowledge is created and shared among its members [5]. This implies that classrooms should provide opportunities for students to become active participants in the learning process especially, in Mathematics instruction.

In the academe, students have this inherent ability to push oneself in acting and engaging in a cognitive activity for learning and development. This motivation is needed to be understood and optimized to encourage the students to participate actively in the study of Mathematics. Together it will be aided by the exploration of cognitive loads for the appropriation of tasks provided to students. This study explored various cognitive loads that may optimize participation among learners as they study Mathematics. Student engagement, formative assessment, and Eureka Math, among others were analyzed as part of the TPTs. This way, the researchers were able to identify some factors that affect student's performance. As various cognitive loads were explored, the study adds up to what may encourage learners to actively participate during Mathematics instruction

2 Literature Review

IT was agreed in the mathematics education community that high participation is useful when it is accompanied by interesting and challenging mathematics [8]. Mathematics instruction needs to provide students interesting and challenging tasks for them to participate actively in the field. As cited by Mesa, the Professional Standards for Teaching Mathematics claims that worthwhile learning of Mathematics by the students depends on how their teachers use or provide mathematical tasks that engage their interests and intellect. Mesa

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also stated that if these tasks are implemented well in the classroom, it will aid in the development of students' understanding, as well as maintaining their born curiosity, and thus enable them to have conversation to their co-students about Mathematical ideas [8],[12].

Research shows that in common mathematics classrooms, daily mathematics instruction usually involves teachers and students engaging in undemanding activities that do not challenge metacognition, such as recalling facts and applying well-rehearsed procedures to answer simple questions. As a result, these strategies of teaching do not promote students' active participation, especially in difficult subjects since these tasks are neither challenging nor interesting. And though, it was found out that the formulation of teaching strategies that promotes challenging tasks in the field of Mathematics are difficult for the teachers [15], it is still essential for them to regularly apply teaching strategies that uses cognitively challenging tasks. These tasks must focus on how to promote students' active participation, an increase in their understanding, the development of their problem solving and reasoning skills, and an increase in their overall achievement [6].

In the classroom, the teachers have the freedom to use their professional judgement to decide and plan on the most appropriate teaching strategies that meet students' needs and provide the necessary content to be learned. Also, teachers should be able to consider the mental capacity of their students and the factors that may affect this. These factors are known as cognitive loads which can be categorized as intrinsic cognitive loads, germane cognitive loads, and extraneous cognitive loads. Intrinsic cognitive load, as described by Sweller, states that instructions have its existing difficulties which cannot be altered by the teachers [16]. However, it was also discussed that many schemas may be broken into individual 'subschemas' and taught separately, then later will be brought back together to form a combined whole [3]. On the other hand, teachers must take into consideration students' intrinsic load, for them to properly apply their chosen teaching strategy in Mathematics instruction. "As teachers, there are huge demands on our time, so when considering a new strategy, it is essential to evaluate the evidence," tweeted by William [17]. Such evidence includes students' prior knowledge and the teachers' judgment on how the understood the topic being discussed [14].

According to David, extraneous cognitive load, in contrast to intrinsic cognitive load, can be controlled by the teachers as they are the designers of teaching instructions [3]. He further explained that this is generated by the way how the information was presented by the teachers to the learners. As stated by Shibli and West, poor teaching strategy such as the use of traditional method of teaching leads to overload in the working memory, and so too much time will be spent in the instructions as opposed to new schema formation [14]. In this case, the teacher must be sensitive on the strategies that will be applied in the teaching process for this will greatly affect the behavior and attitude of the students toward the subject. As a result, it is suggested by Van Merriënboer et al., to apply simple-to-complex sequencing teaching strategy to try to reduce cognitive load [9]. As emphasized by Sweller it is encouraged for the germane load to be optimized [16]. Germane load is the load dedicated to the processing, construction and automation of schemas [3]. Research shows that same as the extraneous load, germane load can be influenced by the instructor [3], [14], [16]. As a result, since these two loads can be altered by the teacher, it is best to use teaching strategies that promotes germane load and lessen extraneous load. As a result, Renkl and Atkinson suggested the use of scaffolding as a teaching strategy to optimize germane load [13]. They recommended beginning the instruction with a model, then gradually removing completed steps, so the learners will have to perform on their own, and finally allowing them to actively participate as they work together in solving the problem.

Participation can be classified into various forms of engagements; bottom-up, top-down [11], motivational drive, communication mode, consultation mode, and deliberative and co-productive mode. Bottom-up engagement is a form of participation led by individuals or groups with limited formal decision-making power. In this form of engagement, participation shows weaker motivation. On the other hand, top-down engagement, as the opposite of bottom-down engagement, is led by those with formal decision-making power that allows every member of the party to contribute to the decision-making process. This engagement reflects democracy and produces stronger motivation. As for the motivational drive as a form of engagement, it can be subdivided into two – pragmatic and normative approach. "Pragmatic motives may be linked to the pursuit of outcomes relating to the decision or issue in which publics and/or stakeholders are engaged (such as environmental protection), whereas motives that are more normative or that seek to build trust and learning may be more likely to target benefits for participating individuals or groups [4]."

And lastly, communication mode, consultation mode, and deliberate co-productive mode of engagement deals on the ways in which participation is accepted or deemed to be valid. Communication mode may be a one-way approach in which a participant or group of participants may work on a task and not receive a feedback; consultation mode provides feedbacks on the participants. The top-down engagement provides opportunity to all members to exchange and formulate decisions, goals, and outcomes to one another. Participation as explained earlier has different forms of engagement and as these engagements vary, the outcomes for the participation also differ. These outcomes can be categorized with based on the following criteria: context, design, power, and scalar fit. In the study conducted by Clancy, it was proven that applying different teaching strategies that cater the total participation techniques enables an improvement on the motivation of the students to participate in the discussion [2]. According to one of his claims in his study, "The total average percent of off-task behaviors, during whole group instruction, decreases with the implementation of a total participation technique." He explained here that with the implication of total participation techniques in the teaching strategy, students became more engaged and focused on the discussion even in the field of Mathematics.

Himmele and Himmele cited a lot of teaching strategies to cater total participation for the students [7]. Total participation techniques inside the classroom can come in various ways (e.g., think-pair-share, quick writes, networking sessions, quick draws, chalkboard splash, card hold ups, etc.). These strategies when properly executed does not only ensures an improvement on the engagement of the learners in the discussion but also triggers their higher-order thinking skills. One example is on the networking sessions. To execute this, the whole class will roam around talking to each of their classmates whom they have not been speaking to on that day; they will continue to roam and communicate with each other until a prompt have been developed. This activity allows participation of the whole class and develops higher-order thinking skills by allowing them to analyze and connect the concepts being discussed with their personal experiences or knowledge. Cognitive Load Theory (CLT) allows an interaction between the components of information and the understanding of human cognition to determine instructional design [10].

Himmele and Himmele suggested that to ensure cognition in the class activity, real-life tasks must be provided to force complex understanding in the learning process. According to them, “First, the complexity, or intrinsic cognitive load, of such tasks is often high so that new methods are needed to manage cognitive load. Second, complex learning is a lengthy process requiring learners’ motivational states and levels of expertise development to be considered. Third, this perspective requires more advanced methods to measure expertise and cognitive load so that instruction can be flexibly adapted to individual learners’ needs.” Many studies and literatures have been developed to establish the acquisition of total participation techniques considering the cognitive loads of the students and how it will be catered via the enhancement of the engagement of learners during class discussion.

3 Methodology

THIS study applied a descriptive research design to ensure that the factors needed to be investigated will be properly studied. Survey technique was applied by the researchers through the investigation of various cognitive loads to generate new ideas and assumptions regarding the empowerment of participation of the students in the subject of Mathematics. The data were gathered from 287 Public Junior High School Students of San Pedro Relocation Center National High School (its main campus and its two annexes – Landayan campus and Cuyab campus) and 60 Public Junior High School Teachers from the same school who are dealing with the subject of Mathematics. The reason for this was, because the selected area for the study has a lot of students and teachers that may be essential for the data gathering process in the research. The research gathered its data from the students from the three campuses of San Pedro Relocation Center National High School and the teachers from the same school. The sample size was obtained through the application of the Slovin’s formula. Stratified random sampling technique was applied in the selection of respondents of the research. Primarily, ethical concerns were considered in this research for the data gathering process. Since individuals were used in the data gathering, it was necessary to consider ethics in research. Data to be collected were obtained through various means such as observation method, content analysis, and using survey questionnaire. For the conduct of the data gathering, instruments were provided for the researchers to properly collect the necessary information. As stated previously in the data gathering procedure, informed consent and request letter were used for persuading the respondents to participate in the research. And, observation method, content analysis and survey questionnaire were used as the means of collecting the information about the research topic. Once necessary information was collected, descriptive, and inferential statistics were applied for the data analysis.

4 Results and Discussions

THE gathered data were analyzed, through the application of appropriate statistical tools and were presented through tables with verbal interpretations.

TABLE 1
RELATIONSHIP OF COGNITIVE LOADS TO TOTAL PARTICIPATION

Indicators	Context			
	r-value	p-value	Degree of Correlation	Analysis
Extraneous Load	-0.576	0.155	Moderate	Not Significant
Germane Load	-0.784	0.041	Strong	Significant
Intrinsic Load	0.366	0.272	Weak	Not Significant
Indicators	Design			
	r-value	p-value	Degree of Correlation	Analysis
Extraneous Load	-0.597	0.144	Moderate	Not Significant
Germane Load	-0.488	0.202	Moderate	Not Significant
Intrinsic Load	-0.146	0.408	Very Weak	Not Significant
Indicators	Power			
	r-value	p-value	Degree of Correlation	Analysis
Extraneous Load	0.336	0.290	Weak	Not Significant
Germane Load	0.320	0.300	Weak	Not Significant
Intrinsic Load	-0.922	0.013	Very Strong	Significant
Indicators	Scalar Fit			
	r-value	p-value	Degree of Correlation	Analysis
Extraneous Load	0.316	0.302	Weak	Not Significant
Germane Load	-0.299	0.312	Weak	Not Significant
Intrinsic Load	-0.597	0.144	Moderate	Not Significant

Significant at $p<0.05$

The table discussed the relationship between the cognitive loads and total participation. Based on the statistical data, this showed a significant rela-tionship between germane load and context. Germane load obtained an r-value of -0.784 ($p<0.05$) and so, the relationship is significant. The relationship among the different cognitive loads and design were also presented.

All the cognitive loads showed an insignificant relationship in connection to design. The cognitive loads have negative correlation in relation to design. And, since the $p>0.05$ all the cognitive loads cannot be deemed related to design. This means that germane load is negatively correlated to context and it was proven significant with the p-value compared to an alpha level of 0.05. The table also showed the relationship between the cognitive loads and power. Based on the presented data, among the other cognitive loads, intrinsic load yielded a significant relationship to power. However, it has a negative correlation since an r-value of -0.922 was obtained ($p<0.05$). This suggests that intrinsic load is inversely related to power. An increase in the students' intrinsic load does not guarantee an increase in power. As stated by Sweller, there exists various difficulties in the instruction which cannot be altered by the teachers [16]. Germane load and intrinsic load have a negative correlation in relation to scalar fit, in contrary to the positive correlation obtained by extraneous load. On the otherhand, evidence should be evaluated to choose the proper teaching strategy and, applying those that cater total participation techniques (e.g. cognitive activation) enables an improvement on the motivation of the students to partici-pate in the discussion [2], [17]. However, since the $p>0.05$ all the cognitive loads cannot be deemed related to scalar fit as a factor for total participation.

TABLE 2
DIFFERENCES AMONG COGNITIVE LOADS IN TERMS OF TOTAL PARTICIPATION

Teaching Strategies	Total Participation					
	Context		Analysis	Design		Analysis
	F-value	p-value		F-value	p-value	
Extraneous Load	2.582	0.029	Significant	1.082	0.385	Not Significant
Germane Load	0.356	0.950	Not Significant	1.098	0.381	Not Significant
Intrinsic Load	0.822	0.558	Not Significant	1.428	0.222	Not Significant

Teaching Strategies	Total Participation					
	Power		Analysis	Scalar Fit		Analysis
	F-value	p-value		F-value	p-value	
Extraneous Load	2.135	0.064	Not Significant	0.777	0.592	Not Significant
Germane Load	0.802	0.617	Not Significant	1.454	0.191	Not Significant
Intrinsic Load	2.451	0.036	Significant	0.35	0.907	Not Significant

Significant at p<0.05

This presented the link between the cognitive loads considered by the teachers and the factors influencing the total participation. It was shown that the cognitive loads that is significantly different to the others in relation to context is extraneous load. Extraneous load, at a value of $F = 2.582$ ($p<0.05$), was found different from the other cognitive loads in relation to context. In line to this, in terms of power, intrinsic load at ($F=2.451$), $p<0.05$ also yields a significant difference, among others. However, it was stated that the more extraneous load exists, the lesser the effect of intrinsic load and germane load to the students so, it is encouraged to optimize the germane load among others to ensure active participation in Mathematics [16].

5 CONCLUSION

FROM the findings, the following conclusions are obtained to answer the general question in the study. As, analyzed from the results, it was concluded that there is significant difference among the cognitive loads in terms of total participation. Since the three yielded differences among the factors of total participation, it is best to optimize the most essential among them. And previous research has already suggested to optimize the germane load to enhance the student's participation. It was also suggested to use cognitive activation as one of the many teaching techniques to earn total participation among the students. Considering the conclusions of the study, the following recommendations are given. Curriculum developers may consider the various cognitive loads of the students in providing worthwhile lessons and relevant activities. School Administrators may provide more trainings for the teachers that will empower their knowledge about the various cognitive loads. They may also provide full support to the students in terms of their needs in the participation as based on the four factors for total participation. Teachers may empower the cognitive loads of the students by continuously considering these in providing activities in Mathematics. Students may be considerate in performing in Mathematics class. This may be done by looking through the four factors for total participation and how these may affect them in their participation. Future researchers may conduct a study related to this were they may focus on the exploration of the teaching strategies. In this way, the idea for the exploration of the factors that influences total participation of the students will be whole.

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