Utilizing Jamovi Software as Tool for Mathematical Modelling towards Agency for Critical Citizenship

Jimbo Juanito B. Villamor
jimbo.villamor@student.ateneo.edu
Ateneo de Manila University, Philippines
jjvillamor@ssct.edu.ph
Surigao del Norte State University, Philippines

Catherine P. Vistro-Yu
cvistro-yu@ateneo.edu
Ateneo de Manila University, Philippines

Abstract: *The challenging reality in today's volatile, uncertain, complex, and ambiguous (VUCA) world has compelled teachers to recalibrate the teaching-learning processes. With the rapid advancement in technology, mathematics educators must aim to integrate technological tools in providing highly engaging learning tasks for the advancement of students' cognitive abilities. This study investigates the potential of employing a technological tool in mathematical modelling towards student agency for critical citizenship. An explanatory sequential mixed methods research design was used to examine the students' level of performance in the mathematical modelling project and to explore how students develop agentic capacities in learning mathematics and competences for critical citizenship. Quantitative and qualitative data obtained through a survey, observation using a video recording, qualitative documents, and focus group discussion among 30 purposively chosen student-participants were analyzed using frequency counts, percentages, mean, standard deviation, paired-samples t-test, and thematic analysis. The study argues that a technology-mediated mathematical modelling project has the potential power to ignite mathematical understanding, build student agency, and develop behaviours for critical citizenship.*

1. Background of the Study

With the recognition of the critical roles that mathematics plays in the world, mathematics education has long emphasized the need to develop students' mathematical understanding and their positive behaviors towards learning mathematics. To address this call, teachers have become more driven to provide students with rich and meaningful learning opportunities essential in concretizing mathematical knowledge, and are important for becoming active, responsible, engaged, and future-ready citizens [8,9,22]. Preparing students for their future could mean teachers' understanding of their students' need for a strong sense of agency, a sense of accountability in meaningfully contributing to society within the environmental, economic, and social contexts [22]. In a mathematics classroom, the development of agency may be possible with a technology-mediated mathematical modelling project that also features environmental and social contexts. Thus, this study explores the use of Jamovi software as a technological tool in mathematical modelling for the development of agentic capacities that could drive behaviors for critical citizenship among senior high school students.

Agency is the ability of people to regulate and control their cognition, motivation, and behaviour through what they believe in about themselves [1]. It is a sense of students who consider themselves as possible actors in society [7]. The sense of agency in students could be developed when they are better equipped with learning opportunities that help them reflect on their sense of purpose and the capabilities essential in shaping their respective lives in order to complement the lives of those around them [22]. These learning opportunities may include mathematical modelling projects or activities that focus on solving real-life problems, and are implemented with technological tools. In a mathematics classroom, the use of technology is beneficial for student learning [4]. Technology-mediated mathematics instructions help students become motivated and enhance their spatial abilities [15]. It provides students with skills and the ability to communicate effectively, think critically, work effectively in teams, and generate original ideas [12].

The existing technological tools for teaching and learning shifted the focus of mathematics education from merely calculating and executing procedures to realistic mathematical thinking [5]. This paradigm shift provides a practical way in learning mathematics and to understand the world. There have been studies in the past noting the great advantage of integrating technology in mathematics instruction. However, the potential of using Jamovi software as a tool for mathematical modelling towards student agency for critical citizenship had not yet been explored in depth.

This present study seeks to provide insights into how technological resources like Jamovi software can be used in a mathematical modelling project centered around solid waste management issues. Consequently, it delves into how such a learning experience is able to facilitate students to acquire mathematical understanding, develop observable capacities and behaviors of agency, and characteristics for critical citizenship. Specifically, this paper addresses the following research questions:

1. What are the levels of students' performance in technology-mediated mathematical modelling?
2. How does technology-mediated mathematical modelling influence student agency?
3. What knowledge, skills, attitudes, and values are essential to building student agency for critical citizenship from a technology-mediated mathematical modelling?

This study recognizes that these capacities and characteristics can be established and understood with technologically-enriched mathematics instruction. The use of technology in mathematical modelling is deemed relevant to help students understand the importance of using mathematics in finding feasible solutions to an environmental problem. It is hoped that when students are exposed to such technology-mediated mathematical modelling projects, they develop a sense of mathematical understanding beneficial to becoming critical citizens.

2. Theoretical Background and Literature Review

This ongoing study rests on the theoretical perspectives of critical mathematics education. Mathematics education for critical citizenship was used to ascertain that students are actively engaged as critical members of society [19,20]. The idea of critical citizenship used in this paper is taken from Skovsmose's notion of mathematics education for critical citizenship. That is, mathematics is essential for people to be able to participate in democracy effectively, empowering citizens to be active and critical members of their societies [19,20]. This study also anchors on the socio-critical perspective of mathematical modelling, which emphasizes that mathematics plays a critical role in society [9,10]. The development of mathematical modelling tasks follows the transdisciplinary lesson and unit framework, which strives to bring together many different disciplines in education towards exploring complex global issues, calls students to engage in local investigations, and helps them take some actions [13]. These perspectives situate the learning environment to offer students relevant experiences for critical citizenship, using the real world.

To describe how students' agency in learning mathematics is developed, this study also adopts Bandura's theory of human agency. Agency includes intentionality or the will to act; forethought or the anticipation of outcomes; self-regulation or actions, processes, and strategies of achieving goals;

and self-efficacy or the evaluation of one's personal belief in what they can do, be they actions, processes, and strategies [1].

In this study, we assert that one way to build agency in learning mathematics is through mathematical modelling themed with transdisciplinarity and technology. With the use of technology, such mathematical modelling activity links mathematics education and the socio-ecological concerns. Such a case makes use of the physical and social phenomena to establish a critical understanding of the world [21] and engages students in learning opportunities as critical citizens so they can be better prepared for the future [14].

3. Research Methodology

Research Design

This study makes use of the explanatory sequential mixed methods research design to explain in detail and in depth the quantitative results using the qualitative data obtained; hence, the quantitative data are systematically linked with the qualitative data. Typically, the use of explanatory sequential mixed methods research design involves the collection of survey data, the analysis of the data, and then followed up with appropriate qualitative data collection techniques to help explain survey responses [3]. While the aim for mixed methods research is to explore and then describe in rich detail the phenomenon that is being investigated, the explanatory sequential mixed methods design is found relevant in carrying out the plans of this study; that is, to build students' agency for critical citizenship using technology-mediated mathematical modelling project centered on solid waste management issues.

Context

In the context of this study, the mathematical modelling task is a mathematical modelling group performance task integrated in the regular mathematics instruction on 'Functions and Their Graphs' in a senior high school General Mathematics course of the Philippines' Department of Education (DepEd). This mathematical modelling project explores a socio-ecological issue in the research environment, attempting to describe the solid waste status in the students' local community. To do this, the actual amount of solid waste, both biodegradable and non-biodegradable, which was collected from 389 households in the local community, was used as the basis for a mathematical modelling project. From this project, students generated linear equations in slope-intercept form, using linear regression performed in Jamovi software. Samples of the tasks are provided below and in the Appendix A (See page 12).

In this activity, you will explore a socio-ecological issue by examining the solid waste status of your local community. The data on biodegradable and non-biodegradable waste collected from 389 households will be used as the basis for your work. Your tasks are as follows:

1. Use the given data to perform a linear regression analysis in Jamovi.
2. From the results, generate linear equations in slope-intercept form that will serve as mathematical models of the community's solid waste status.
3. Apply these equations to predict the future amount of solid waste in your local community.
4. Based on your predictions, propose actionable solutions that can help mitigate solid waste management problems.

Figure 3.1 The Mathematical Modelling Task

Sampling and Participants

The study was implemented in one of the protect group of islands in Mindanao, Philippines. Purposive sampling was employed in choosing 30 student-participants of the national science high school enrolled in a Grade 11 class taking the General Mathematics course in school year 2023-2024. This particular school was chosen because it offers an advanced mathematics and science program in the island.

Research Instruments

Research instruments used in this study include the researcher-designed mathematical modelling (MM) project, researcher-developed scale instrument for student agency in learning mathematics (SALM), and interview guides on student agency and critical citizenship. Each of the instruments underwent a systematic validation process to ensure that the items accurately measured the intended constructs. For the SALM, content validity in terms of relevance and clarity was established through the evaluation by three (3) psychologists or psychometricians. The instrument was then pilot tested with 323 students, resulting in an acceptable reliability index. Similarly, the items in the MM project were subjected to expert review by three (3) specialists in mathematics or mathematics education before being pilot tested with 39 students.

Data Collection and Data Analyses

The students were divided into six groups with five members each. To maintain the integrity of their work, each group performed the mathematical modeling project separately in designated vacant classrooms to avoid overhearing one another's discussions. Prior to the analysis phase, a two-week orientation on the use of Jamovi was conducted, with one-hour sessions designed to familiarize the students with the software's features and navigation. During the orientation, emphasis was placed on performing linear regression analysis. This served as the foundation for the next steps: (1) conducting the linear regression in Jamovi, (2) generating linear models based on the results, (3) using these models to forecast future waste data, and (4) proposing solutions to help manage waste based on the forecasts.

With the students' consent after being explained with the confidentiality agreement of this study, each group's discussions was video recorded using cellular phones. An audio-recorded focus group discussion (FGD) was carried out to determine their thoughts and feelings while performing the mathematical modelling project. The students' outputs, video-recorded group discussions, and audio-recorded FGD were the main sources of data. The students' outputs served as the basis for determining the students' performance in the tasks, while the transcripts of the video- and audio-recording were used to establish understanding of how students developed agency and critical citizenship as they performed the task.

The collected quantitative data were analyzed using frequency counts, percentages, mean, standard deviation, and paired samples t-test. Qualitative data were analyzed using a thematic analysis.

Ethical Considerations

This study obtained an ethics clearance from the University Research Ethics Office (UREO) of Ateneo de Manila University, with Protocol ID numbers: SOSEREC_23_002 and SOSEREC _23_002CA, specifying that individuals' participation in this study is voluntary and does not affect their grades. The student-participants were not harmed during the conduct of the study and were assured that their responses would be handled with utmost confidentiality.

4. Findings

Students' Performance in a Mathematical Modelling

The students' performance in mathematical modelling is measured across the suggested assessment features from the Guidelines for Assessment & Instruction in Mathematical Modelling Education [6]. There were some modifications implemented since the mathematical modelling tasks were designed to address a solid waste management issue in a research environment. Thus, the features assessed include (1) defining the modelling problem and building the model; (2) mathematical solution and analysis of the model; (3) feasibility of proposed solutions; and (4) organization of thoughts. In this paper, we define these features as mathematical modelling competence.

The competence in defining the modelling problem and building the model includes the ability to define the modelling problem, make assumptions, acknowledge limitations, define variables, and identify parameters. Mathematical solution and analysis of the model comprises the use of meaningful mathematics, accessibility of results, analysis, and assessment of the model. The competence in the feasibility of the proposed solutions indicates the possible impact of the proposed idea to help mitigate the solid waste management problem. The competence in organization and presentation includes writing style, organization of ideas, and presentation skills. The performance level from each of these features was described using the mean, standard deviation, and percentages. The description of the students' performance was anchored to the assessment guidelines of the Department of Education (DepEd) per DepEd Order # 8, s. 2015. Three (3) groups were found to have outstanding performance, very satisfactory, satisfactory, and fairly satisfactory. In terms of defining the problem and building the model, most groups had better scores, suggesting that students generally understood the modelling problem well and could translate it into a model, although there is slight room for improvement in clarity or completeness. In terms of mathematical solution and analysis, scores are high overall, demonstrating solid mathematical thinking and accuracy. In terms of the feasibility of proposed solutions, scores are more variable, suggesting that their proposed solution may vary in realism, practicality, or clarity of the mitigating measures. In terms of organization of thoughts, most groups presented their ideas in a clear and logical way. Table 1 presents the students' overall performance across the features of mathematical modeling.

Table 1. Students' Performance in Mathematical Modelling by Feature

Features of Mathematical Modelling	**Score**	**Total Points**	**% Score**	**Performance Level**
Defining the Problem and Building the Model	8.33	9	93%	Outstanding
Mathematical Solution and Analysis of the Model	9.50	11	86%	Very Satisfactory
Feasibility of Proposed Solutions	4.17	5	83%	Satisfactory
Organization of Thoughts	4.50	5	90%	Outstanding
Total	**26.50**	**30**	**88%**	**Very Satisfactory**

Legend: Outstanding (90-100%); Very Satisfactory (85-89%); Satisfactory (80-84%); Fairly Satisfactory (75-79%); Did Not Meet Expectations (Below 75%)

The students generally had a 'very satisfactory' performance in the task. Their ability in both defining the modelling problem and building the model, and in organization and presentation was 'outstanding', which demonstrates a mastery level. Their performance in mathematical solution and analysis of the model was 'very satisfactory', which indicates a thorough and solid performance, but might need only minor areas for improvement. Their performance in the feasibility of the proposed solutions was ‘satisfactory’, which implies that the offered solutions were adequate and acceptable, but may still need deep insights and creativity. Overall, the students’ performance in the task is strong, above average, and consistently good across most features.

The above results revealed that the students’ competence in a technology-mediated mathematical modelling project generally reached an acceptable learning performance. Here, technological tool, specifically, the Jamovi software, is able to help students navigate the task. Their mathematical knowledge was enhanced with the use of technology.

In fact, when students were asked to describe the solid waste status of their community, their outputs reveal an interesting use of technology. Figure 4.1 shows a sample output of Group 6. This image shows a bar graph generated using Jamovi, a user-friendly statistical software designed for easy data analysis and visualization. The graph compares the amount of non-biodegradable waste (in grams) based on two waste disposal practices: segregated and segregated. The use of Jamovi in this output highlights how technology enhances data analysis in environmental science education. Jamovi enables users, even those without programming backgrounds, to visually present complex data. This student’s output, with the use of technology, effectively communicates the comparison between disposal practices, which might otherwise be lost in raw data tables.

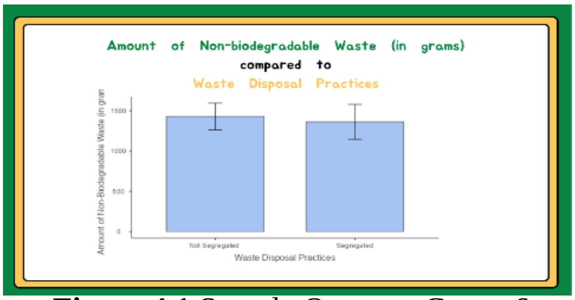

Figure 4.1 Sample Output – Group 6

Figure 2 presents a slide containing a data-driven observation using Jamovi, which showcases scatter plots and regression models to analyze the relationship between the number of hours accumulated and the amount of biodegradable and non-biodegradable waste disposed. With the use of technology (Jamovi, in this case), modeling data is made accessible. Additional samples of student’s outputs can be accessed online through this link:
https://drive.google.com/drive/u/1/folders/1U_zw9eQ9cKFaAM0GbOuu6hhLm2Rv0zmA

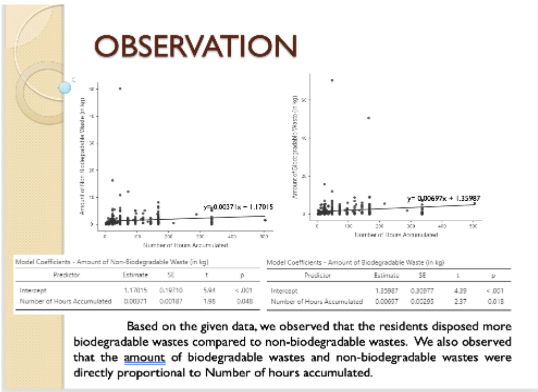

Figure 4.2 Sample Output – Group 2

Jamovi enabled students to create linear regression models even without advanced programming skills. This empowers senior high school students to test hypotheses and examine trends. The clean visual output from Jamovi allows for student's effective presentation of their findings, bringing clarity to the relationships of the amount of solid waste and accumulated and in environmental data.

The Influence of Mathematical Modelling to Student Agency

The integration of technology-mediated mathematical modelling in the classroom showed interesting effects to student agency. In context, agency is the students' ability to direct and manage their own learning through intentionality, forethought, self-regulation, and self-efficacy [1]. Table 2 displays the level of student agency in mathematical modelling.

Table 2. Level of Student Agency in Mathematical Modelling

Features of Agency	Period	Mean	SD	Qualitative Description
Intentionality	Pres-exposure	3.90	0.37	High
	Post-exposure	4.22	0.44	Very High
Forethought	Pres-exposure	4.11	0.43	High
	Post-exposure	4.54	0.37	Very High
Self-regulation	Pres-exposure	3.71	0.46	High
	Post-exposure	4.20	0.47	Very High
Self-efficacy	Pres-exposure	3.44	0.49	High
	Post-exposure	3.96	0.55	High

Legend: 4.20-5.00 (Very High), 3.40-4.19 (High), 2.60-3.39 (Moderate), 1.80-2.59 (Low), 1.00-1.79 (Very Low)

Before exposure to the mathematical modelling task, the students' agentic capacities were generally high across the four core features. After exposure, their agentic capacities increased from high to very high levels within the capacities for intentionality, forethought, and self-regulation, except for self-efficacy, which remained at the high level, but with a greater mean score than their pre-exposure to the mathematical modelling task.

A series of paired-samples t-test were conducted to determine whether mathematical modelling led to a significant change in students' agentic capacities. The analysis compared students' self-assessment scores obtained before (pre-test) and after (post-test) the exposure to the mathematical modelling task, summarized in Table 3.

Table 3. Paired Samples t-Test Comparison of the Level of Student Agency Before and After Mathematical Modelling

Features of Agency	Student's t statistic	Mean Difference	p	Interpretation	Effect Size
Intentionality	4.20	0.322	<.001	Significant	0.766
Forethought	5.39	0.429	<.001	Significant	0.983
Self-regulation	5.94	0.489	<.001	Significant	1.085
Self-efficacy	5.92	0.516	<.001	Significant	1.081

Note 1. $H_a\ \mu_1 \neq \mu_2$

Note 2. $0.20 \leq \eta^2 \leq 0.50$*:(small effect),* $0.50 \leq \eta^2 \leq 0.80$*: (medium effect),* $\eta^2 \geq 0.80$*: (large effect) (Cohen, 2013)*

Findings indicated that post-test scores for intentionality, forethought, self-regulation, and self-efficacy were significantly higher than their respective pre-test scores. The positive t-values indicate that the difference was calculated as post-test minus pre-test, which confirms, through Cohen's $d \geq 0.766$, a substantial and statistically significant improvement in students' agentic capacities following the integration of a mathematical modelling task mediated with a technological tool (Jamovi).

The above results aligned with Drijvers' claim that the use of technology was found to be beneficial for student learning [4]. Using technology in mathematics teaching and learning motivates students to learn [15]. Technology, like Jamovi, is able to facilitate students' development of effective communication skills, critical thinking, and collaboration [12]. With technological tools, mathematics teaching has shifted from mere calculation and execution of procedures to authentic mathematical thinking [5].

Essential Knowledge, Skills, Attitude, and Values towards Building Student Agency for Critical Citizenship

In light of the above results, students were subjected to a focus group discussion after performing the mathematical modelling project in order to understand the students' performances. Agentic capacities were observed among students, evident from their responses on the use of technology (Jamovi) in mathematical modelling. These capacities include intentionality, forethought, self-reactiveness, and self-reflectiveness, parallel to Bandura's conceptualization of human agency.

> *Student 7: Through the use of Jamovi, I learned that scatter plots can help us see how scattered the data we gathered. I also learned that linear regression can help us generate some formulas that can make predictions… I learned the importance of slope-intercept and scatter plot in predicting the amount of solid waste with reference to our collected data.*

> *Student 11: When we were introduced with the Jamovi, we thought this is very useful. Through this, we first encounter scatter plot at the first time, because what we always encountered were the simple ones: pie chart, bar graph.*

> *Student 20: The Jamovi software helped us identify the key factors affecting waste generation, such as financial income and household status within the community. The software also provided graphs, which made it easier for us to analyze the data… Even though the process was challenging, we became eager to learn how to analyze and interpret the data. Our knowledge and conceptualization skills became more enhanced, until we were able to present our findings at school and in the community. Through this, we were able to formulate plans in optimizing solutions, and contribute to addressing solid waste management issues in the entire community.*

Across students' reflections, students demonstrated agency to varying degrees. Intentionality, an individual's will to act, was seen as they used Jamovi with a clear purpose: to understand data through scatter plots and regression in order for them to predict solid waste accumulation (Student 7, Student 20). Forethought, the anticipation of outcomes, was evident in the idea of applying Jamovi to community concerns and planned solutions based on their data analysis (Student 20), by linking statistical concepts to future predictive applications (Student 7), and by acknowledging Jamovi's potential use in future research (Student 11). Self-regulation, the student's ability to monitor and adapt their learning process, was apparent in students' reflections to overcome challenges, becoming eager to learn, and reflecting on the growth of their conceptual skills (Student 20), and by connecting new insights to prior knowledge (Student 7). Self-efficacy, the belief in one's capability, is also manifested in the conversation. Students confidently applied their learning to interpret data and make meaningful contributions, especially in real-world contexts (Student 7, Student 20), and acknowledged Jamovi's ease of use in mathematical modelling (Student 7).

Characteristics of critical citizenship were also observable across students' reflections. Students demonstrated varying degrees of mathematical, technological, and reflective knowledge in the context of using Jamovi in mathematical modelling. Mathematical knowledge was visible as students showed a deeper understanding of mathematical concepts such as scatter plots, linear regression, and data interpretation (Student 7, Student 20). They pointed out the connection of statistical results to the slope-intercept form of linear equation (Student 7), applied mathematical thinking to identify relationships between community variables and waste generation (Student 20), and noted exposure to new types of graphs like scatter plots beyond the more familiar pie and bar charts (Student 11). Technological knowledge was demonstrated through the students' use of Jamovi as a data analysis tool to effectively generate graphs and simplify analysis (Student 20), utilized it to generate formulas and make predictions (Student 7), recognized Jamovi's ease of use compared to SPSS (Student 11), a clear indication of students' awareness of technological tools. Reflective knowledge was noticeable as students discussed how performing mathematical modelling with Jamovi helped them overcome challenges, enhance their conceptual skills, and apply insights to community issues like solid waste management (Student 20). They have also recognized the value of the mathematical concepts learned and their relevance in real-world (Student 7), and the usefulness of the Jamovi in performing the mathematical modelling task (Student 11).

The Use of Jamovi as a Tool for Mathematical Modelling

Rapid advancement in technology has prompted mathematics educators to integrate technological tools into their lessons. The findings prove that mathematical modelling projects foster students' ability to see the world through a scientific lens [11]. Specifically, the use of Jamovi as a tool for mathematical modelling enhanced both students' mathematical ability and agentic capacities. This result could be attributed to the type of socio-ecological problem used in the mathematical modelling project, and to the mode of implementation, which relied on the use of a technological tool such as Jamovi.

The integration of collaborative, open-ended mathematical learning projects grounded in realistic situations and supported by technology enabled students to exercise greater agency in learning mathematics. Through these technology-aided projects, students recognized the value of their actions and gradually shaped themselves into critical citizens. In particular, the mathematical modelling project, carried out with Jamovi, fostered behaviors aligned with critical citizenship—such as critical thinking and decision-making, the ability to form sound opinions, ethical and social reasoning, and the capacity to conceive actions that can effect meaningful change. We posit that the use of technology, specifically Jamovi, in mathematical modelling projects enhances students' critical understanding of their world. This aligns with the idea that strong and enduring democracies are sustained by citizens who are critically minded and actively engaged in civic affairs [16].

In the context of classroom discussion, Jamovi played a central role by opening new educational spaces for mathematical exploration [10]. It created opportunities for students to collaboratively analyze real-life problems, test ideas, and articulate insights, thereby enriching dialogue and reflection. The strategic use of Jamovi not only deepened students' understanding of mathematical concepts and relationships but also supported their engagement and participation in discussions [17]. Indeed, technological integration in mathematics instruction holds transformative potential for reimagining how students learn and interact with mathematics [18].

Conclusion

This study contends that engaging students in a technology-mediated mathematical modeling project using Jamovi holds significant potential to ignite mathematical understanding, strengthen student agency, and cultivate behaviors aligned with critical citizenship. The findings highlight that mathematics teachers can effectively integrate Jamovi into their instruction—not only in mathematical modeling projects but also in other classroom activities—to foster higher-order cognitive skills and positive dispositions toward learning mathematics. Furthermore, mathematical modeling tasks are most impactful when they address relevant social issues that students can meaningfully relate to, thereby bridging mathematics education with other disciplines and real-world concerns.

Future research may extend this work by examining mathematics teachers' lived experiences in facilitating modelling tasks with Jamovi, exploring teacher agency in technology-integrated instruction, and investigating professional development programs that prepare educators to implement mathematical modelling with technological tools effectively.

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APPENDIX A

MATHEMATICAL MODELLING TASKS IN GENERAL MATHEMATICS

Topic: Functions and Their Graphs

Content standard: The learners will be able to demonstrate understanding of key concepts of functions.

Performance standard: The learners will be able to accurately construct mathematical models to represent real-life situations using functions.

Task 1: Mathematical Modelling on Managing Solid Waste in Your School

Context: Your school practices a regular waste disposal on a daily basis. Conduct a survey on the amount of solid waste your school produced in two weeks. Describe the amount of these wastes using a mathematical linear model. From the result, predict the amount of solid waste your school will produce in the coming weeks. What can you do to manage these solid wastes?

Task 2: Mathematical Modelling on Managing Solid Waste in Your Community

Context: Your local government initiates a regular collection of household solid wastes in your community. Conduct a survey on the amount of solid waste your community produced for two weeks. Write a mathematical description of these wastes with the help of a linear model. Predict the amount of solid waste your community will produce in the coming weeks. How can you help manage these solid wastes?