ENHANCING STUDENTS' UNDERSTANDING THROUGH MATHEMATICS PROJECTS – A MATHEMATICS TEACHER'S EXPERIENCE

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ABSTRACT

With an increasing need to broaden and expand the students' understanding in mathematics in the classroom, the creation of a variety of teaching and learning tools and strategies are of utmost importance. Using the appropriate teaching and learning form, opportunities can be provided for students to develop necessary skills and demonstrate their understanding in relevant areas. For the two mathematics courses in the CIMP curriculum, namely Mathematics of Data Management and Advanced Functions, mathematics projects are part of the teaching and learning activities that provide the opportunities for students to fulfill the expectations of the course and at the same time, enhance their degree of understanding of the concepts and ideas introduced. In this paper, the author will highlight the mathematics projects devised for both courses and share the experience and feedback from students on what had been implemented and learnt throughout the semester. Also, the hands-on experience with concepts and ideas, the skills developed and achievements made, as well as the constraints and challenges confronted will be discussed in the paper.

Keywords: Mathematics, teaching and learning.

INTRODUCTION

With an increasing need to broaden and expand the students' understanding in mathematics in the classroom, the creation of a variety of teaching and learning tools and strategies are of utmost importance. The teaching and learning tools selected must suit the students' needs and be able to equip and prepare them with the knowledge and skills for their chosen tertiary education. In addition, the selected strategies and tools can provide some insights for the teachers in their assessment of the students' achievement in the relevant course of study. According to the Ontario curriculum documents, the achievement demonstrated should cover all four categories of the Achievement Chart, which are Knowledge and Understanding, Thinking/Inquiry, Problem Solving, and Communication and Application (Ministry of Education, 2007). Besides these, the students' learning skills including various aspects such as Work Habits, Organization, Independence, Teamwork and Initiatives are measured and used to improve student learning.

In the Canadian International Matriculation Programme (CIMP), students' progress is measured through continuous assessment where opportunities are provided for students to develop their full potential and demonstrate their understanding in various areas relevant to the subject matter. With a 70% coursework and 30% final examination programme structure, students in CIMP benefit tremendously due to the nature of the programme offered. However, student success is very much determined by regular and consistent efforts

as there are many tasks to be covered and completed such as tests, quizzes, assignments, projects, research tasks, individual and group presentations and many more. The nature of the tasks assigned is influenced heavily by the type of subject matter advocated at the teachers' discretion, but in general, almost all courses in CIMP assigns an independent project commonly known as ISU (Independent Study Unit), as part of the assessment and evaluation process and is incorporated in the teaching and learning activities in and out of class. The project assigned is rather unique and normally serves as a culminating task that often occurs at the end of a unit or semester, and requires students to integrate their knowledge and skills to solve a complex, multi-stage problem or task.

In this paper, the author will highlight the mathematics projects devised for two mathematics courses, Mathematics of Data Management (MDM4U) and Advanced Functions (MHF4U), and share the experience and feedback from students on what had been implemented and learnt throughout the semester. The hands-on experience with concepts and ideas, the skills developed and achievement made as well as constraints and challenges confronted will also be discussed in the paper.

DESCRIPTION OF THE MATHEMATICS PROJECTS

Under the two CIMP mathematics courses, namely Mathematics of Data Management (MDM4U) and Advanced Functions (MHF4U), mathematics projects are integral parts of the teaching and learning activities that provide the opportunities for students to fulfill the expectations of the courses and at the same time, enhance their degree of understanding of the concepts and ideas introduced.

Mathematics of Data Management (MDM4U)

For MDM4U, the project assigned encompasses various aspects of the prescribed curriculum expectations in the Grade 12 Mathematics Ontario Curriculum. The expectations are integrated into stages or phases involving the many parts to be completed ranging from the formulation of thesis statement based on the topic selected, creation of a questionnaire and many more. The phases are referred to as Progress Checks and the required items for each phase are specified accordingly in the handouts provided to the students. For each phase, a suitable deadline will be indicated and students must submit the items for teacher's assessment by the stated date. These due dates are provided at the commencement of the project, which normally takes place after the completion of the first unit on Statistics. This strategy will provide the students the opportunities to plan ahead and manage their time to work on relevant items for timely submission.

Another requirement of the project is that the students are requested to work in groups, normally in groups of 3 or 4. This will help them to complete the many phases together and at the same time, allow them to learn from each other. Team members who have sound background in Mathematics can definitely help the others who are not quite well-versed with the materials required for the phases involved. Additionally, a group leader must be appointed once the group is formed in order to ensure that all instructions are relayed and understood by all members. In other words, the group leader will not only

manage the group but at the same time, serves as a liaison person between the group and the teacher.

The items to be covered for the project include almost all topics in the Statistics component of MDM4U such as Measures of Central Tendency, Measures of Spread, Graphs, Correlation and Regression, as well as Probability. With this, the students can connect the lessons and skills learnt in class with their culminating project. To add more interesting features to the culminating project, the students can choose their own topic, write the relevant thesis statement and design their own questionnaire to collect the data or primary source of information. In addition, the students are requested to conduct background research based on the topic selected, which will serve as a secondary source of information and undergo a short exercise on referencing activity to avoid issues of plagiarism in preparing their oral presentations and final reports.

Table I below highlights the phases to be completed for the project on Statistics & Probability.

Table I. Stages for Statistics and Probability Project for MDM4U

PHASES OR PROGRESS CHECK	**DATES** (Subject to changes)	**AGENDA** (Items to be completed and submitted)
INTRODUCTION	FEBRUARY 3	INTRODUCTION TO ISU Topic of interest, Thesis Statement & Method of Data Collection - refer to Guide : Introduction to Statistics & Probability Project
QUESTIONNAIRE DESIGN & BACKGROUND RESEARCH	FEBRUARY 10, FEBRUARY 11, FEBRUARY 12 & FEBRUARY 13	QUESTIONNAIRE DESIGN & BACKGROUND RESEARCH i) Read Chapter 2 (text, Section 2.4, page 103) ii) Design a questionnaire in class on February 10 – refer to sample provided for the format iii) The DRAFT copy of the questionnaire is needed at the beginning of the class on February 11. Failure to submit the draft on time would result in a penalty of 2% iv) Conduct a research on the topic chosen, and bring along related articles (as secondary sources of information) for a class activity on referencing on February 12 v) Finalized questionnaire is needed by February 13
TOPIC & DATA COLLECTION	FEBRUARY 20	INSPECTION ON THE TOPIC SELECTED & METHOD USED TO COLLECT DATA – refer to Guide #1
ONE-VARIABLE	FEBRUARY 27	CHECKING THE CALCULATIONS ON MEASURES OF CENTRAL TENDENCY

STATISTICS Part I		(MEAN, MEDIAN & MODE) – refer to Guide #2 i) Measures of Central Tendency to be submitted on February 27 ii) Bonus : Accurate formula for median and mode – due on March 3
ONE-VARIABLE STATISTICS Part 2	MARCH 6	CHECKING COMPUTATIONS ON STD. DEVIATION & INTERQUARTILE RANGE – refer to Guide #3 i) Measures of Spread are due on March 6
VISUAL DISPLAYS OF DATA	MARCH 20	GRAPHING STAGE : HISTOGRAM & CUMULATIVE FREQUENCY CURVE (COMPULSORY GRAPHS) – refer to Guide #4 i) Graphs to be submitted on March 20 ii) Bonus : Additional graphs for the qualitative data due date : March 25
TWO-VARIABLE STATISTICS & PROBABILITY (Q & A session)	APRIL 2	PREPARATION FOR PRESENTATION – refer to Guide #5 i) Presentation outline to be submitted on April 8 ii) Submission of Correlation & Regression section & Probability components for teacher's perusal on April 10
ORAL PRESENTATIONS	APRIL 13 – 17	PROJECT PRESENTATIONS (in class) i) Powerpoint (PPT) presentations - formal dress-code ii) No extension of date regardless of missing members
FINAL REPORTS (Q & A session)	APRIL 24	DISCUSSION ON FINAL REPORTS - refer to Guide #5 i) Pay attention to the checklist provided. Samples of previous reports can be viewed again
SUBMISSION OF REPORTS	MAY 6	SUBMISSION DATES FOR FINAL REPORTS i) A must for all to submit on the scheduled dates, otherwise marks will be deducted – i.e. 5 marks for each day late

Advanced Functions (MHF4U)

For MHF4U, the projects assigned are divided into two components due to the different requirements to be fulfilled. As an example, two projects named Growing Beans and Creating 3D Theme Park are presented. Both projects were devised for the first time during the July 2008 semester.

The projects are normally carried out in groups of either 3 or 4, with a team leader appointed for the same reasons as the above course, that is, to manage the team and delegate the tasks among the members as well as act as a liaison person between the teacher and the team.

For the Growing Beans project, each group must select a different type of beans and conduct a study on the selected beans to understand the planting requirements better. The type of soils and fertilizers to be used and the amount of watering utilized should also be considered in order to ensure that the planting process works smoothly and successfully. All materials to be used are prepared by the groups on their own with advice and guidance from the teacher. Handouts or information sheets will also be provided by the teacher to guide the groups from one phase to another.

As part of the activity, the height of the plants is measured on a daily basis for further mathematical analyses based on the course expectations. Each group is responsible for taking care of the planted beans by watering them and observing or recording the daily changes to the plants. The targeted duration for the planting session is between 3 to 6 weeks, with 2 to 3 replicates for comparing the results. Once the data is gathered, mathematical analysis is conducted which will be shared with other teams during the Power-point presentation in class.

For the project on Creating 3D Theme Park, students utilize their knowledge and skills in building the various rides for their theme park. Students are allowed to choose their own theme based on their experience. They can use any material to build the rides but they have to consider the mathematical properties of each ride to relate to the course content and expectations as outlined in the curriculum documents for MHF4U.

Working in groups of 3 or 4, again, the students jointly contribute their ideas and creativity in creating attractive rides. The time given is approximately 3 weeks and each group is requested to produce the rides in three-dimensions on a poster (minimum size of a standard cardboard) and should provide the relevant features of each ride based on the requirements stipulated during their presentations in class. The students must also explain the strengths and attractiveness of their created theme park and reasons why their creation should be selected as the best theme park.

The following tables, referred to as Table 2-A and 2-B for the Growing Beans project and Table 3 for the Creating 3D Theme Park project, provide the requirements and purposes of each progress check in brief including the timelines for the phases involved for both projects. Note that there are two parts for the Growing Beans project, namely Part A for the Introduction and Planting Session and Part B for Data Analysis and Presentations.

Table 2-A. First Phase for Growing Beans Project

PROGRESS CHECK FOR PART A	**DATES** (Subject to changes)	**AGENDA / PURPOSES** (Items to be completed and submitted)
INTRODUCTION	AUGUST 13	Introduce the Growing Beans Project – refer to Guide
REFERENCING ACTIVITY & RESEARCH MATERIALS	AUGUST 14	Purposes: i) To understand better the type of beans to be planted ii) To formulate the proper procedures for growing the beans iii) To learn about the APA Referencing Style and understand better the CIMP Policy on Plagiarism Note: Referencing Activity sheet to be returned on the next day with copies of relevant secondary source of information on the selected beans
DISCUSSION & DELEGATION OF TASKS	AUGUST 15	Purposes: i) To ensure each team member contributes equally to the project based on the delegation of tasks ii) To answer any queries resulting from the different viewpoints of the team member iii) To be prepared for the starting date of planting the beans iv) To allow for better communication & correspondence
PLANTING THE BEANS	BEGINNING AUGUST 25, 2008	Items required for each group: i) Seeds from the selected bean ii) Suitable pot(s) of any size (consider the other aspects such as watering, air-flow etc to ensure well-draining soil) iii) Check out the type of soil suitable for the type of bean and fill in the pot with the desired soil. Wet cotton is also possible iv) If compost is used, another pot as 'a control specimen' must be prepared, that is, one pot with fertilizer and another without fertilizer to make comparison of results v) Anything else desired, such as poles to support the plant or netting to cover it etc
COLLECTING DATA	MEASURING HEIGHT. EFFECTIVE DATE: Depends on the germination rate of the plant	Purposes: i) To measure the height of the plants on a daily basis and record all data on a sheet designed by the group. Information required : Day vs. Height, and other pertinent observation or changes observed on the plants ii) To provide the raw data for the next stage – analyzing the data and matching the type of function.

Table 2-B. Second Phase for Growing Beans Project

PROGRESS CHECK FOR PART B	**DATES** (Subject to changes)	**AGENDA / PURPOSES** (Items to be completed and submitted)
DATA COLLECTION & TABULATION	First submission – after about 2-3 weeks Second submission – after about 4-6 weeks	Purposes: i) To keep track of the processes involved ii) To allow students to take charge of the assigned tasks and rectify any problems that arise Note: Do check with the teacher to view a sample of data tables
DATA ANALYSIS & PREPARATION FOR SLIDES PRESENTATION	Prior to the presentation date, October 15, 16 and 17	Items to be prepared: i) Create scatter plots using MS Excel ii) Perform all types of regression as discussed in class iii) Select the best model that fits the data set based on the results obtained in (ii). Explain in detail on the choice made and provide reasons iv) Investigate further the relevant numerical properties of the function used to represent the data v) Make predictions based on the equation generated. Use at least 5 different x-values to get the predicted y-values. Comment whether the values generated are reasonable vi) For the slides presentations scheduled on October 15, 16 and 17, present the solutions to the parts above and insert all relevant information such as the background information of the beans selected, table of the raw data (day vs. height) and related materials for Growing Beans Project
PRESENTATION DAYS	OCTOBER 15, 16 & 17	Marks will be rewarded based on the following criteria using the Rubric on PPT Presentation i) Presentation Skills ii) Mastery or Level of Proficiency on the subject matter iii) Creativity and Thoroughness in presenting the solutions using technology iv) Preparedness (for the presentation and Q & A session)

Table 3. Creating a 3D Theme Park (Begin October 24, due date November 17)

REQUIREMENTS:

1) Discuss with your group members the types of theme parks that you have been to. Have your members brainstorm the rides and attractions that they have seen at these parks.
2) Consider the equations of the graphs that you have learned in this course and which can be applied to the rides at the theme parks.
3) Create your own theme park by incorporating the information gathered. You can be as creative as

you wish, but make sure that the types of functions used are related to the course content.
4) Include the equations of the rides and the descriptions on how they work. Also, provide reasoning on the appropriateness of the ride to the age of the rider. In other words, you have to consider the appropriate ride for different age groups of the riders and create your rides accordingly.
5) The map of your theme park will be presented in the form of a three-dimensional poster. Be creative and artistic in building the rides and other attractions in your theme park.
6) Marks will be awarded on the following criteria:
   i) The identification of the right and appropriate functions for the rides.
   ii) Explanation and description of the rides with respect to the age of the riders.
   iii) Interesting layout and creative rides or attractions for the visitors. (Note: You may use any material suitable for the ride, the sturdier the better).
   iv) The more functions used, the more marks you will be rewarded. BE CREATIVE!

SKILLS DEVELOPED AND ACHIEVEMENTS MADE

Two separate surveys were conducted during the semesters July 2008 and January 2009 to gather the information and feedback from students based on the skills that they have developed and achievements made while doing the projects. The surveys were completed by 80 students, who volunteered for both courses, MDM4U and MHF4U, and the results obtained are shown in Table 4.

Table 4. Percentage of Responses for the Skills Developed by Students (Total=80 students)

Skills Developed	Percentage of Positive Responses
Time Management	87.5%
Teamwork	100.0%
Leadership and organizing	62.5%
Tolerance and patience	81.3%
Perseverance and determination	60.0%
Sense of Commitment	6.25%

Of the 80 students surveyed, 70 respondents claimed that they have polished their time management skills due to the nature of the projects (87.5%). Since the timelines were provided ahead of time, the students were able to plan and manage their time in order to fulfill the requirements outlined. The fear that marks would be deducted for late submission encouraged the students to take their responsibilities seriously and earnestly. Most group leaders also played a major role in ensuring the timely submission of the items.

As for teamwork, all respondents agreed that they developed better teamwork skills when doing the many phases of the projects. They had to collaborate with the team members in order to carry out the tasks regardless of the disagreements that occurred due to the differences of ideas, abilities and level of understanding among the members.

Fifty respondents (62.5%) believed that they had refined their leadership and organizing skills while doing the projects. The majority was group leaders and they appreciated the fact that they had been appointed to take the role. However, some of them

commented that they had to be the mediator when disagreements took place among the members. A few leaders mentioned that they had to take over when the members had no clue on the assigned work. But, they felt such an opportunity helped them to understand the materials better and become good leaders.

Tolerance and patience are considered another skill developed among the respondents where 65 of them believed that they had learned to understand others better. They claimed that due to the differences in human characters and abilities, they had to tolerate some of the members who seemed to have lack of understanding in mathematics and were not capable of doing the work correctly without guidance from the others.

Forty-eight respondents (60%) had changed their perceptions in studies and life as they learned to be more persevering and determined in taking over the responsibilities. Their ultimate goals were to finish the projects on time and complete the many phases to the best of their abilities and score good marks. Therefore, they managed to change their attitudes toward schoolwork as they worked hard to complete the projects.

Five students (6.25%) had renewed their sense of commitment when they prioritized on what should be completed on the day-to-day basis. Some sacrificed their time to complete the tasks for the projects instead of hanging out with friends. But they were satisfied as they earned good marks for the projects.

ACHIEVEMENTS MADE BY STUDENTS

Almost all of the respondents indicated that they had improved on the usage of technology for these projects. Quality of information presented was enhanced with the appropriate use of technology and the presentations were done with creativity and enthusiasm.

For MDM4U students, the majority of them believed that the assigned project had improved their level of understanding on Statistics and Probability. They commented that the project also served as a revision on the lessons taught in class and they could apply the mathematical ideas and concepts on real-life problems. In addition, almost all of the respondents claimed that they managed to successfully create probability questions related to their topic of interest, and understand the probability theories better.

As well, MHF4U students had the same notion as they indicated that their level of understanding was enhanced when they successfully applied the concepts on Polynomial Functions and Mathematical Models for the two projects assigned.

A few students believed that they worked well with their team members and met the specified deadlines. In other words, they successfully cooperated and fostered good teamwork for these projects. Communication process among team members took place with success and students' interpersonal skills also improved tremendously.

CONSTRAINTS AND CHALLENGES FACED

Despite many good comments and feedbacks made by students on these projects, there were some instances involving a few groups whereby the members faced difficulties in carrying out the assigned tasks.

Five groups from both courses could not complete the work on time due to the

incapability of the leaders to manage the members and delegate the tasks as required. This occurred as the members involved did not have sufficient level of understanding on the subject matter and they procrastinated all the time. Quality of work was missing due to the lack of organization and commitment from the members. Absence from class was another reason contributing to the problems above.

Three groups have disagreements from time to time due to the differences in opinions and ideas. Leaders of the said groups liked to dictate to members to do the work and provide wrong instructions as they interpreted the tasks differently. Members were not satisfied and they blamed each other for their mistakes. At the end of the day, they marked each other very low on teamwork during the peer assessment exercise.

Another challenge faced was the preference of the students when it comes to forming groups. Almost half of the students preferred to work with the same people that they had worked before for other assignments and they happened to also choose people with the same nationalities due to reasons of convenience, easy communication and same background level and experience in Mathematics.

Furthermore, selection of members was based on gender where female students would prefer to work with other female students, and the same applies for male students. At the same time, when forming groups, members were also selected based on the level of confidence on the members' ability to complete the tasks and understand the requirements of the projects. In other words, if the members had a strong background in Mathematics, they will be chosen to be part of the groups and the weaker ones might be left out in the formation of groups.

One big challenge that the teacher had to contend with was the fact that there was time-constraint for these projects. This is inevitable for the two courses, namely MDM4U and MHF4U as normal lessons and other coursework must still be carried out and these will take some portion of the class instructional time. There were too many things to be done and students had little time to spend on these projects in class. So, when students encountered problems and needed further guidance, they had to meet the teacher outside the class time, email the teacher personally or post their concerns on Discussion Board via the Blackboard e-learning portal.

SUGGESTIONS AND RECOMMENDATION

In solving the problem on student procrastination and reliance on others to complete their work, it is recommended that a contract be designed and signed by team members. The contract will indicate that the members have to contribute a fair amount of time, energy and effort in completing the many phases of the project. As well, the contract should have clauses on the consequences of breaching the contract such as penalties, warnings and the worst - withdrawal from the group. Disagreements among team members can also be avoided when such a contract exists.

As for the preference of team members for the same nationality or gender, or having strong background in Mathematics, it is advisable for the teacher to specifically state that there should be mixed groups of females and males, different nationalities and also, mixed abilities in Mathematics. The teacher can help the students in forming the groups if they are not able to form the groups as desired; bonus marks could be awarded if the students

manage to form the required groups.

In enhancing students' understanding and learning, there are some principles that can be adapted based on the "Seven Principles for Good Practice" (Chickering & Gamson, 1987). It is recommended that there should be frequent student – instructor contact in and out of classes as this serves as an important factor in student motivation and involvement. Teachers who are concerned and frequently help students through difficult times can enhance students' intellectual commitment. On the same note, students can evaluate themselves in terms of their values and future endeavors.

In addition, learning can be enhanced when it is conducted as a "team effort rather than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others normally increases involvement in learning. Sharing one's own ideas and responding to others' reactions improves thinking and deepens understanding" (Chickering & Gamson, 1987). Such principles are well integrated in the projects devised above.

Good teaching and learning practices also involve prompt feedback which is included in the projects above. The teacher will schedule brief meetings during the progress checks and advise the students on their work accuracy and provide tips on correcting their mistakes. With this information, students will be motivated to improve on their work.

The MDM4U and MHF4U projects, in some ways, recognize and respect diverse talents and abilities of students. As the students complete the many phases of the projects, there are rooms for creativity and wit to prosper. Students are rewarded with bonus marks for going beyond the expected requirement and this is highlighted by the teacher in class to motivate others to do the same.

CONCLUSION

Participation in the kind of projects described in this paper will not only enable students to earn marks, but at the same time, allow them to improve and develop good skills such as time management, teamwork, leadership and organization. Students can also polish their communication skills, interpersonal skills as well as improve their level of confidence while doing the project. Most importantly, the students who have given their full commitment and enthusiasm for the project, will undeniably improve their level of understanding of the subject as they can successfully apply the concepts and ideas introduced in class throughout the many phases of the projects.

The project also encourages an active learning environment as students will not only just learn by sitting in classes, listening to teachers, memorizing assignments, and regurgitating the answers. Students are given the opportunity to talk about what they are learning, research and write about it, relate to the concepts taught, and apply what they learn on the assigned project. Thus, it provides meaningful learning opportunities for the students and in turn, prepare the students for their university education.

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