

INTERDISCIPLINARY RESEARCH AND WRITING IN MATH COURSES

David L. Harness
Christopher B. Fisher¹
Department of Mathematical Sciences
United States Military Academy
Thayer Hall, Room 218
West Point, NY 10996
david.harness@usma.edu
christopher.fisher@usma.edu

Introduction

In mathematics courses, teachers often encourage students to learn and embrace math by applying it to solve problems that arise in everyday life. To this end, teachers develop or design projects. The unstated claim is that encouraging students to conduct research, solve problems, and communicate results of mathematical analysis will help them learn math and how to apply it. The question is, how do we find projects that will motivate and / or encourage students to fully work a problem in a way that will enhance their mathematical understanding.

United States Military Academy Core Math Program Goals

The United States Military Academy (USMA) has established specific goals that all lessons and activities within a core mathematics class support or attempt to accomplish. The core math courses are the three courses that all USMA Cadets must take, specifically MA103, Mathematical Modeling and Introduction to Calculus; MA104, Single Variable Calculus; and MA206, Probability and Statistics. The specific goals are shown in Figure 1, below.² The goals, which are hierarchical and build upon on another, are establish a body of knowledge, communicate math, refine technology skills, hone problem solving techniques, develop interdisciplinary problem solving skills, and finally, establish habits of mind.³ These goals are incorporated into all core math courses, and USMA math instructors develop projects with these goals in mind.

¹ The views expressed herein are those of the authors and do not reflect the position of the United States Government, the United States Army, or the United States Military Academy.

² Department of Mathematical Sciences, *Core Mathematics* (West Point, NY: United States Military Academy, 2016), 11.

³ Department of Mathematical Sciences, *Core Mathematics* (West Point, NY: United States Military Academy, 2016), 11-13.

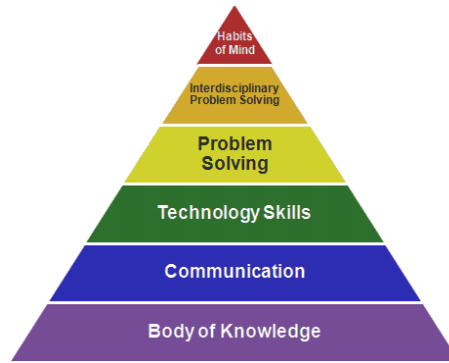


Figure 1: USMA Core Math Program Goals

The United States Military Academy Mathematical Modeling Process

USMA has established a process for modeling real world situations. Figure 2, below, depicts this.⁴ This USMA Mathematical Modeling Process (USMA MMP) includes three major steps: transform, solve, and interpret.⁵ It is an iterative process through which a mathematical analyst refines a model in order to provide a decision maker or customer with results and advice. In the transform step, an analyst assesses the real world situation in order to develop a model by defining variables, identifying assumptions, and choosing a modeling strategy. In the solve step, the analyst using the mathematical model to actually solve the problem, arriving at a solution he or she can further analyze. In the last step, interpret, the analyst assesses the reliability and accuracy of the solution, and communicates it to the decision maker or customer. Finally, the analyst updates any assumptions or facts, and steps through the process again, if necessary.

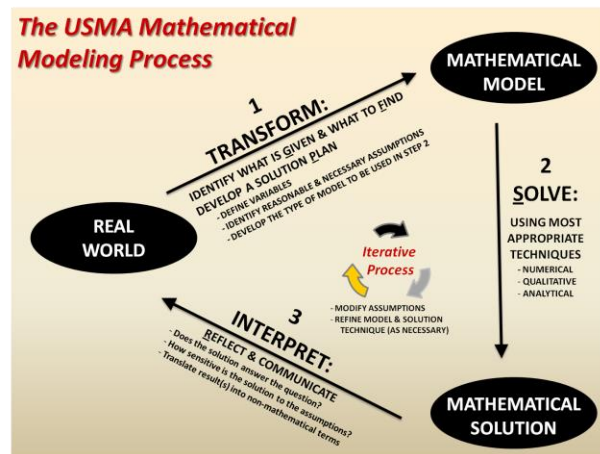


Figure 2: The USMA Mathematical Modeling Process

⁴ Department of Mathematical Sciences, *Modeling in a Real and Complex World* (West Point, NY: United States Military Academy, 2016), Figure 1.4.

⁵ Department of Mathematical Sciences, *Modeling in a Real and Complex World* (West Point, NY: United States Military Academy, 2016), 6.

Project Design and Purpose

With the Core Math Program Goals and the Mathematical Modeling Process in mind, instructors can develop projects that enhance student understanding of mathematics (Figure 3). This paper proposes some underlying features that projects should have in order to motivate and encourage students. These features are interrelated and influence one another. Further, they are related to the components of experiential learning as outlined by Marilla Svinicki and Wilbert McKeachie in *McKeachie's Teaching Tips*.⁶ The five features discussed in this paper are real world, interdisciplinary, stakeholder consideration, ill-defined guidance, and buy in.

Real World

For students to be interested in a project, it may be useful for them to see it as being part of the real world. By this, we mean that a student should be able to perceive the subject of the project as living in his or her own world. Often times, instructors develop real world problems that deal with subjects or topics with which the student has no experience or familiarity, such as physics related topics, for example. Such topics may not successfully pull a student in and encourage him or her to fully engage with the project. Thus, developing a project that impacts or pertains to the student's world is advisable.

Interdisciplinary

Since many of our students will never be science, technology, engineering, or mathematics (STEM) majors, their interests lie in other disciplines. Due to this, developing projects that are interdisciplinary may be of more interest to students. These other disciplines may be other academic disciplines, such as finance or psychology. Or, these disciplines may be other non-academic areas of interest, such as sports or fashion. This feature, interdisciplinary, ties in directly with the real world feature.

Stakeholder Consideration

Projects that require stakeholder consideration are useful to prepare students for the "real world" they will experience after graduation. This feature requires a student to view the problem from the perspective of his or her stakeholder, the customer or the decision maker for whom the student analyst is doing the project or research. The student will have to plan to address the stakeholder's needs and communicate results to him or her. This feature requires an interdisciplinary perspective, as students have to consider human relations and communication techniques. Further, stakeholder consideration is a useful feature since many students will be motivated when they feel that their analysis can help or impact another person's life or business.

⁶ Marilla Svinicki and Wilbert McKeachie, *McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers* (Belmont, CA: Wadsworth, 2014), 204 – 205.

Ill-Defined Guidance

The problems that instructors often present in math classes are very sterile. There is often one, and only one, solution. All the facts a student needs to solve the problem are generally provided, though instructors often provide extra, unnecessary information. Unfortunately, real problems generally are not as neat. Thus, building a problem with ill-defined guidance is a good teaching tool. Students will be required to do research in order to develop reasonable and necessary assumptions to deal with any lack of data. This act of research will enhance the student’s understanding and perhaps even his or her motivation in tackling the project.

Buy In

Finally, buy in is key to project success. Instructors want their students to fully commit to the project and treat it as one that they have a vested interest in completing. Through the other four features, a certain amount of buy in can be enhanced, or maybe even achieved. Buy in can also be considered an extension of the real world feature in which students understand how solving the problem impacts them or their loved ones. In the end, an instructor must develop a project scenario that will speak to the students, pulling them in and establishing buy in.

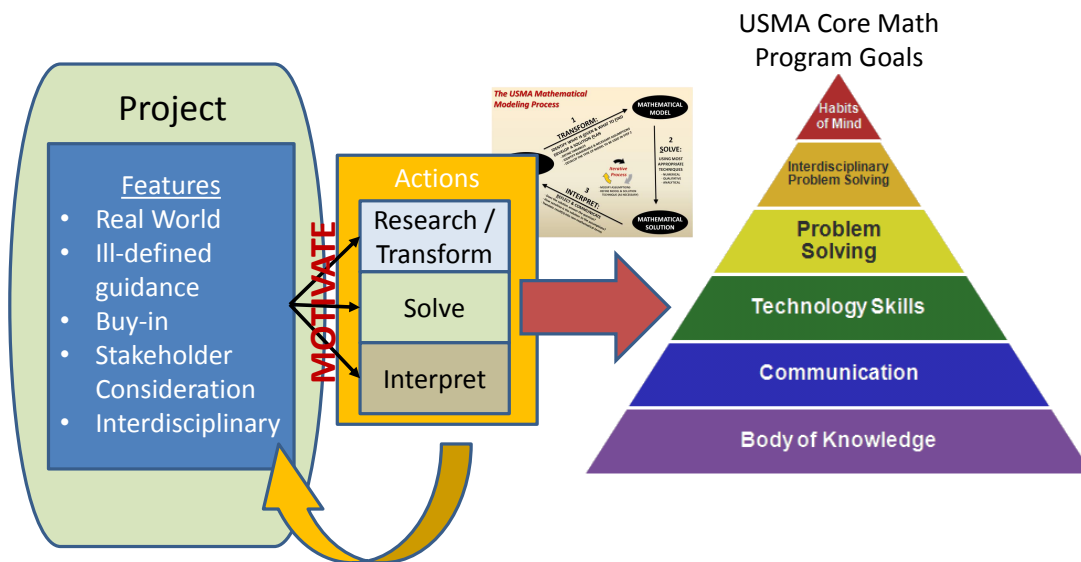


Figure 3: Project Features, the MMP, and Core Math Goals

Example Project: Army Retirement Analysis⁷

An example project that illustrates these five features is one assigned in Math 103, Mathematical Modeling and Introduction to Calculus, at the Military Academy. This

⁷ This project was developed by the MA103 Course Directors, MAJ Ryan Slocum and MAJ Russell Nelson, USMA.

project focused on the Army retirement system, which was undergoing changes in 2016. At this time, there were two systems: the Legacy Retirement System and the Blended Retirement System. Both systems include a pension upon retirement. The newer system, the Blended Retirement System, included an investment, or 401K-like portion. The key difference between the two systems is that the new Blended Retirement System allowed Soldiers to retain some retirement benefits even if they did not complete twenty years of active federal service. The two systems had characteristics as depicted in the table below:

| Retirement System ⁸ | Pension upon 20 years of service | Investment |
|--------------------------------|----------------------------------|---|
| Legacy Retirement System | 50% base pay | None |
| Blended Retirement System | 40% base pay | 401k-like, with matching contributions up to 5% of base pay |

Table 1: Legacy and Blended Retirement Systems Comparison

This retirement project tasked students to determine how the values (quantitative and qualitative) of each of the systems compared to one another. More specifically, the project tasked students to persuade two hypothetical (and undetailed) service members to select the retirement system the student determined was best for that service member. Several deliverables were required, including written and oral presentations. The students had to address the three steps of the MMP: transform, solve, and interpret.

Project Features

This project displays all the features that we propose are key to motivating students. For example, this retirement change was a real one that was happening in the Army at that time, thus it was real world for the students of West Point. The new system will have an impact on the students' financial futures when they commission in the Army, which allowed us gain buy in from the students. We provided ill-defined guidance. Specifically, we tasked students to provide analysis for two hypothetical service members. We did not provide specifics on the members' ages, years of service, or expected number of years of service. This information is necessary to conduct the analysis, so students had to perform research and make assumptions. They also had to research the basics of retirement accounts and investing. These service members for whom the students were conducting the analysis were the stakeholders. Since their financial futures are important to them and their families, the students had to prepare analysis that was specific to that member and communicate the results to him or her. They also had to use appropriate leadership and persuasion techniques to convince the service member to take the identified course of

⁸ "The U.S. Uniformed Services Blended Retirement System at a Glance," Department of Defense, accessed May 19, 2017, https://www.uscg.mil/hq/cg1/cg131/docs/mbr_res/BlendedRetirementSystemInfographic.pdf.

action. Finally, the project was interdisciplinary, as it involved financial planning, as well as leadership techniques the students will use as Army Officers..

Transform / Research

The students had to take the real world situation we presented them, and transform it into a mathematical model in order solve it. Due to the project design, we provided the students with guidance that was ill-defined. They were thus required to research various topics, primarily how interest rates apply to investments and retirement accounts. They also had to do research to understand the typical career / retirement timeline of the service members for whom they would be performing the analysis. We provided the students with a few primary websites to get them started in their research, but from there, they had to find additional resources to make necessary and reasonable assumptions and complete the analysis. This required them to consider the needs of their stakeholders, the service members, in order to research and address all the facets necessary to perform an analysis that would be useful to the stakeholders and their families.

In order to ensure that the students were not making assumptions or finding information that would derail their progress, we conducted in-progress-reviews (IPRs). We conducted these reviews two times between the assignment issue date and the due date. IPRs consisted of the students briefing, or presenting, their progress up to that point directly to the instructor. Instructors were then able to redirect them, as necessary, in order to ensure they were on a correct, analytical path. This would prevent them from working themselves into a situation in which they could not complete the assignment, which would further reduce the chances of us accomplishing the goal of the project: learn math and achieve core math goals.

Solve

The mathematical techniques taught in class were necessary to solve the problem. Additionally, use of technology was a requirement for the project. Not only was technology included in order to enhance student technology skills, but it was necessary to solve the problem in a reasonable amount of time. For this project, we allowed students to use Excel and Mathematica. Once again, audience and stakeholder considerations were important when solving the problem. Students had to ensure they solved the problem in a way that met the needs of the service members for whom they were conducting the analysis.

Interpret

We asked the students to interpret their results through writing and briefing. We required a written document whose audience was the mathematical community, or people more familiar with the math required by the project. This required the students to, once again, view the project form another point of view. The document was a one to two page paper that would explain the problem, methodology, results, and address some sensitivity analysis. Students were required to use the Equation Editor resident in Microsoft Office,

as well as charts and graphs to explain their analysis. We wanted them to carefully choose what should be included in this report and what should not. They were required to address the specific need of this mathematical audience.

The students also briefed their analysis and results to the instructor, who played the part of the service member(s) for whom the students had conducted the analysis. We did not want the students to explain their work as if they were presenting work to an instructor. The students had to consider the backgrounds of these hypothetical service members, who did not necessarily (and probably did not at all) have the mathematical experience to understand the math behind the analysis. We expected the students to explain all their assumptions in order to allow the service members to refute them or set the student analysts straight. The students then explained the results of their analysis and discussed how it impacted the service member in question. We wanted students to present slides that would “tell the story,” and encourage the service member to choose the retirement plan that the student recommended, be it Legacy or Blended. Finally, the students were prepared to answer real-world questions about their analysis and the plans. Specific questions included how the plan impacted the service member’s family or what the service member should do if he chose to leave the Army early.

Impact

Our views of the impact of students completing this project are observational. We did not conduct a formal assessment to determine if conducting this project improved students’ mathematical understanding or improved exam scores. After the projects, we discussed with students their impressions of it. Many reported that they felt that working on a project that applied to their lives was useful. They echoed the sentiment that most projects they have done in math classes have virtual applications, or at least applications with no direct ties to their lives. Further research should be conducted to see exactly how developing projects with the five features impacts student understanding and helps accomplish the USMA Core Math Goals.

Conclusion

In order to encourage and motivate students to commit fully to a mathematical learning experience, instructors should design projects and experiences that draw students in and allow them to see how the math is applicable to them. To that end, we identified five features that are related to those outlined in the book *McKeachie’s Teaching Tips*. These features are real world, interdisciplinary, stakeholder consideration, ill-defined guidance, and buy in. These features may be useful as a framework, or should at least be considered, when developing projects to motivate students. Though it will not guarantee that students will give their full effort when working the project, these features may have lasting effects that will benefit the student in later years.

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