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Transforming Undergraduate Curriculum for Green Plastics Manufacturing Technology

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Transforming Undergraduate Curriculum for Green Plastics Manufacturing Technology (GPMT)

Student-Centered Learning and POGIL Approach

All learning involves knowledge construction in one form or another; therefore, it is a constructivist process.[1,2] Higher education community has strived for reforming undergraduate STEM education, so that traditional lecture-based instructions are transferred to more student-centered-learning formats. Many research articles find that students can learn more through student-centered instructions than traditional-transmission ones in undergradute STEM education. With increasing interest in innovative approaches such as student-centered, active learning, and peer-led team learning, process-oriented-guided-inquiry-learning (POGIL), project-based learning (PBL) and other educational approaches have received attention within the educational communities.[3-6] Particular approaches may be suitable to the specific characteristics of the student and audience, facilities, instructional goals, personal preferences, and educational resources.

The POGIL approach relies on inquiry-based, student-centered classrooms and laboratories that enhance learning skills while insuring content mastery.[7] POGIL is designed to replace traditional lecture-only methods by encouraging students to discuss course materials, rather than listening to the instructor. Literature in the field of student learning indicates that the POGIL approach has been effectively used in disciplines such as mathematics, biology, and chemistry for post-secondary education.[3,4,7]

The innovative POGIL approach is a nationally tested and proven pedagogical strategy that incorporates recent educational research on how students learn from kindergarten through post-secondary education.[7] Figure 1 shows a schematic diagram to illustrate that the POGIL approaches are best suited to meet the ABET criteria, which are based on the industry needs: a skill set of problem solving, critical thinking, information process, teamwork, and management.

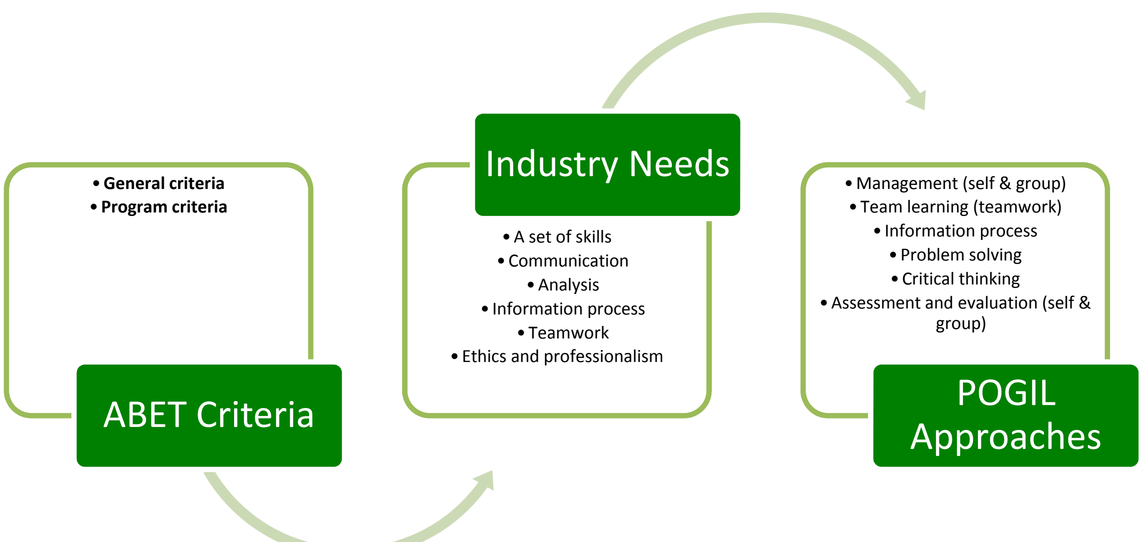

Figure 2: The POGIL approaches adopted for the needs

What is the GPMT?

One of the most important subjects in engineering and technology programs is manufacturing. Manufacturing involves a complex system of materials, machines and people. Plastics manufacturing technology is a multidisciplinary field that deals with product design, prototyping and modeling, production and process design, materials testing and characterization, process automation and robotics, and quality control. “Green Plastics Manufacturing Technology” (GPMT) is an emerging discipline that encompasses a range of activities, such as research and development of non-toxic and eco-friendly materials to the reduction of waste and pollution through changing patterns of production and consumption.

A multidisciplinary field, plastics manufacturing technology deals with product design, prototyping and modeling, production and process design, materials testing and characterization, process automation and robotics, and quality control. “Green Plastics Manufacturing Technology” (GPMT) is an emerging discipline that encompasses a range of activities, from the research and development of non-toxic, eco-friendly materials to the reduction of waste and pollution through changing patterns of production and consumption. The primary approach of the current project (DUE- 1044794) is to develop an instruction model and learning modules in the materials and manufacturing curriculum for future workforce development in Green Plastics Manufacturing Technology. The new learning modules developed by Process-Oriented Guided Inquiry-Learning (POGIL) enhance the STEM education and promotes an intensive undergraduate research activity for the undergraduate students in manufacturing and mechanical engineering technology programs at Rochester Institute of Technology (RIT).[8]

Instructional Model for the GPMT

Figure 2 illustrates a system approach developed as an instructional model in green plastics manufacturing education within the current project (DUE- 1044794). This model that we developed draws upon the analysis of the student’s learning outcomes to redesign an instructional format and to reformulate the instructional strategies for the effectiveness of learning and teaching for evidence-based instructional practices. The formative and summative evaluations helped us optimize the outcomes to improve the instructional methods and develop the definition of evidence-based instructional practices in “Green Plastics Manufacturing Technology (GPMT).”

The optimal method of instruction is to provide desired outcomes in knowledge and skills in the undergraduate STEM education. Therefore, the instructional model is a systematic process so that all the elements of the system (Figure 2) are inter-related to continually monitor the outcomes and modify the instructional model as needed until it reaches the learning and teaching goals for undergradute STEM education; that is, the elements (i.e., instructor, students, course materials, and learning environment) are tightly bounded to work together toward defined educational goals and objectives in the discipline.

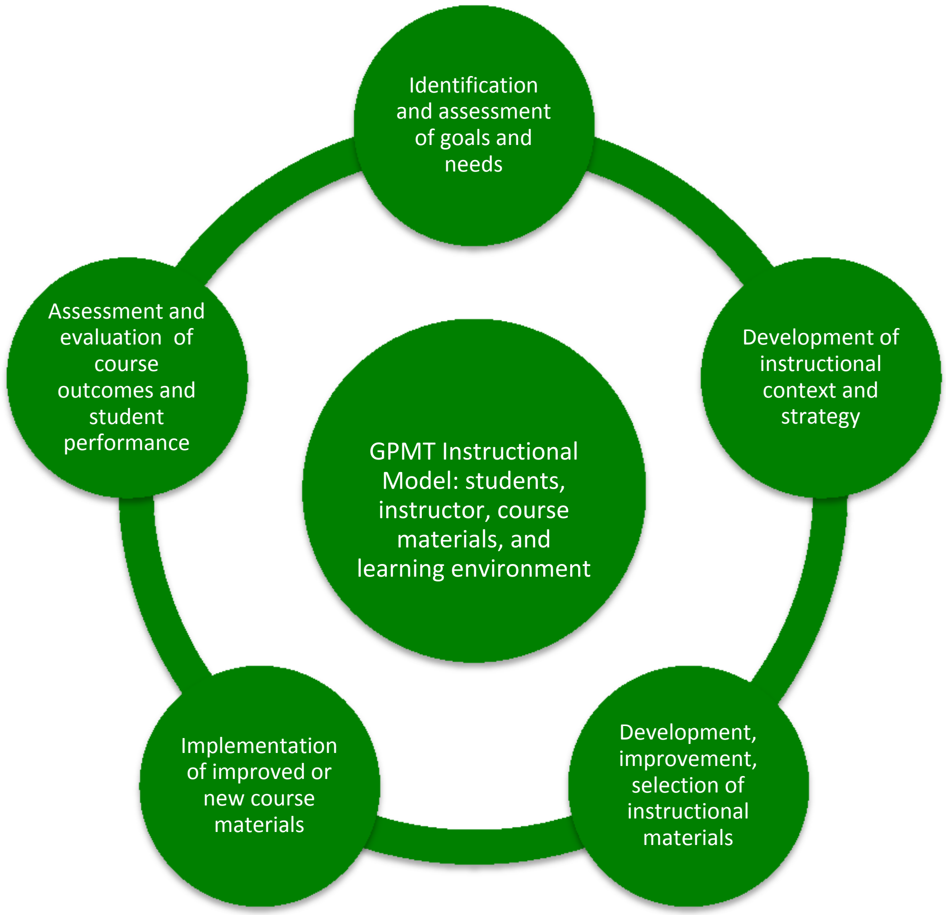

Figure 2: The GPMT Instructional Model

Transforming the Materials and Manufacturing Curriculum

Manufacturing technology is integrally tied to advancements in materials technology. Materials technology has played a critical role in the technological evolution of our society, from structural steels to optoelectronics and robotics technology. We have enhanced the five current core courses: that is, materials technology, mechanical engineering technology lab II, plastics processing technology, solid modeling and design, and robotics in manufacturing. Also, we established an intensive undergraduate research program for co-op students in the manufacturing and mechanical engineering technology programs.

These improved courses deal with more complex materials systems and new manufacturing technologies: such as nano materials technology, green materials and manufacturing, testing and characterization, sustainability, environmental technology, solid modeling, and robotics using the proposed instructional strategies. Therefore, transforming the core materials and manufacturing curriculum will prepare students for entering the field of green manufacturing technology. Students who also engage in the undergraduate research program will offer a strong set of research skills to potential employers in green manufacturing.

Development and Improvement of the Core Curriculum

The following summarizes the course design before and after the improvement of the curriculum according to the strategies proposed.

1. **Course Title: Solid Modeling and Design**

Target Students and Class Size: Freshmen/4 sections of 25 students each
Course Description:
Before: This course introduces students to solid modeling and the engineering design process. Students learn visualization skills, parametric solid modeling and the creation of engineering drawings. Design projects are used to reinforce concepts and to provide practical design experience.
After: This course introduces students to solid modeling and the engineering design process. Students learn visualization skills, parametric solid modeling and the creation of engineering drawings. Design projects are used to reinforce concepts and to provide practical design experience. The projects also introduce sustainability and end of life disposal as a criteria in mechanical design, and will estimate the environmental impact of design and material choices.

2. **Course Title: Plastics Processing Technology**

Target Students and Class Size: Juniors or seniors or graduate/25 student per session
Course Description:
Before: The lecture-oriented course introduces fundamentals in various methods used to manufacture plastic products. Topics include compression molding, rotational molding, extrusion, injection molding, blow molding, and thermoforming in plastics manufacturing.
After: The course contents are developed with laboratory exercises. The course introduces students to various methods used to manufacture plastic products with polymers including green materials; emphasis is placed on the integration of product design, material selection, and process selection by establishing the cost/performance/carbon footprint characteristics of a given product. Hands-on, team-based work is emphasized.

3. **Course Title: Materials Technology**

Target Students and Class Size: Juniors/5 sections of 30 students each
Course Description:
Before: The course considers the interrelation of properties, structure, processing, and performance for non-metallic materials. Emphasis is placed on materials and process selection for design application. Failure mechanisms are discussed, along with ways to minimize the effects of these mechanisms.
After: The course considers the interrelation of properties, structure, processing, and performance for non-metallic materials. Emphasis is placed on materials and process selection for design application with special consideration of their impacts on the environment, economics, and society. The mechanisms of degradation of current and green materials are discussed, along with ways to minimize the effects of these mechanisms in green manufacturing. Students learn

how to reduce the environmental impact of materials on green manufacturing. Materials selection is emphasized in terms of the sustainability and carbon footprint.

4. **Course Title: Mechanical Engineering Lab II**

Target Students and Class Size: Juniors/10 sections of 12 students each
Course Description:
Before: Students characterize polymers, ceramics, and composites by performing tests of mechanical and processing properties according to ASTM and ISO standards. Emphasis is placed on analyzing experimental results and preparing professional-quality laboratory reports
After: Students characterize polymers, ceramics, and composites by performing tests of mechanical and processing properties according to ASTM and ISO standards. Green plastics are evaluated for mechanical and processing property characterization. The bio degradability of green polymer is evaluated by the standard testing as well. Emphasis is placed on analyzing experimental results and preparing professional-quality laboratory reports on the basis of the ASTM and ISO standards.

5. **Course Title: Robotics in Manufacturing**

Target Students and Class Size: Juniors or Seniors/3 sections of 12 students each
Course Description:
Before: The course focuses on the technology and application of robots in a Computer Integrated Manufacturing (CIM) environment. An introductory understanding of robotic hardware and software are provided. The hardware aspects include robot configurations, drive mechanisms, power systems (hydraulic, pneumatic and servo actuators), end-effectors, sensors and control systems. The software aspect deals with the various methods of textual and lead through programming.
After: All of the above remain. The concepts of green materials are added to topics covered. The five include reducing cycle time thus saving energy, multitasking to allow the elimination of less energy efficient equipment, improving quality which should allow for less energy expended in rework, robots recycling, and making sustainable energy products. These five will be studied in lecture and will allow for added laboratory activities.

Assessment and Evaluation of the GPMT

Based on the evidences and findings from the current project, the newly-developed structure for assessment and evaluation is helpful in adopting evidence-based instructional methods, which have a more student-centered learning format. For example, the traditional-transmission learning format, in which the degree of a student's success depends only on the performance of quizzes, tests and projects in class, does not truly reflect the effectiveness on learning.

We adopted more collaborative approaches for this NSF project to break away from traditional norms in education, while assessing students' abilities in various summative cases; many aspects in learning effectiveness are interconnected by the three key components (instruction improvement, learning effectiveness and student performance). As a result of the assessment and evaluation, we were able to identify strengths and weaknesses to reform the traditional-transmission format for students' learning effectiveness in formative and summative purposes.

Findings from the GPMT Practices in 2011-2012 Project Period

The findings from the GPMT project in the 2011-2012 project period are summarized as follows:

1. The new instructional model and curriculum design required the students to work for meaningful learning activities and asked them to think about what they were doing in the classroom.

2. Our new instructional strategies were to improve or develop the materials and manufacturing curriculum utilizing "Process-Oriented Guided Inquiry-Learning" (POGIL). With POGIL, students could acquire key processing skills as they learned the discipline contents.

    - We developed optimal methods of instruction to bring desired outcomes in knowledge and skills in green materials and manufacturing technology for undergraduate students in the engineering technology programs at RIT.

    - The new learning modules developed students to actively be engaged in learning, so a guided learning inquiry could result in the positive attitudes in active learning.

    - Students had a strong interest in learning course materials by the POGIL based learning modules; the students agreed that the new POGIL learning modules helped them improve conceptual development and enhance skills in the courses.

3. We recognized the critical role of the instructor in classroom activities. This reflects a careful re-design of the course in order to insure that the learning module is not simply an activity but to promote an active learning environment for the students.

4. An outreach model was developed for STEM outreach. This model includes the assessment strategy for outreach activities, pre and post surveys for high school outreach, survey for teacher workshops, an assessment report template and a hands-on lesson plan template (http://www.facebook.com/pages/Green-Plastics-Manufacturing-Technology-GPMT/137107806352893).

Conclusion

"Green Plastics Manufacturing Technology" (GPMT) is an emerging discipline that encompasses a range of activities, such as research and development of non-toxic and eco-friendly materials to the reduction of waste and pollution through changing patterns of production and consumption. The primary goal of the project is to transform the exiting materials and manufacturing curriculum to keep pace with the new green technologies in the manufacturing and mechanical engineering technology/packaging science programs at Rochester Institute of Technology (RIT). We developed an educational approach and undergraduate teaching modules for Green Plastics Manufacturing Technology within foundational courses in the materials and manufacturing education. The outcomes of the project bring innovation and changes, not only in terms of creating an effective instructional model for the undergraduate STEM education, but also by encouraging students to do research as they prepare for careers in green plastics manufacturing technology (GPMT).

Acknowledgement

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