1-1-2013

Implementing Process Oriented Guided Inquiry Learning (POGIL) in Undergraduate Biomechanics: Lessons Learned by a Novice

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Abstract

Process Oriented Guided Inquiry Learning (POGIL) uses specially designed activities and cooperative learning to teach content and to actively engage students in inquiry, analytical thinking and teamwork. It has been used extensively in Chemistry education, but the use of POGIL is not well documented in other physical and biological sciences. This is a descriptive account of the initial implementation of POGIL in a university biomechanics course and includes the benefits, challenges and recommendations for teachers interested in using this effective instructional strategy.

Introduction

Undergraduate biomechanics courses are designed to help students develop an understanding of the mechanical and anatomical principles that govern human movement and be able to connect human anatomy to mechanical function (see Table 1). Instructors of undergraduate biomechanics face two significant challenges to engaging students in meaningful learning experiences: 1) students often find that the volume and depth of information in biomechanics is daunting and, as a sub-discipline of physics, can be challenging, and 2) biomechanics students often come from a variety of disciplinary backgrounds and lack common academic preparation.

Biomechanics is traditionally taught via a lecture-lab format. When lecture was used as the primary instructional method by the first author, student engagement and interest appeared to be much lower than for the experiential learning of the accompanying laboratory. Students also did not seem to tie the passive learning of lecture to the active experiential strategies used in lab. In addition, the lecture portion of the course did not seem to be doing much to help students develop non-content area skills needed in the workforce (i.e. interpersonal/teamwork, analytical thinking, flexibility/adaptability, ability to work independently) (NACE, 2011). Moreover, significant portions of the enrolled students were studying to be educators themselves, and the lecture course was not serving those with an interest in having multiple teaching strategies modeled. These perceptions were confirmed by student course evaluations that indicated the lecture was not as engaging as students would have liked and lecture did not enhance their learning as much as the students and instructor had hoped.

In response to these observations and student feedback, a different pedagogical approach to the course, Process-Oriented Guided Inquiry Learning (POGIL), was adopted. The POGIL approach uses specially designed activities and cooperative learning to simultaneously introduce material and actively engage students in key processes, such as analytical thinking and working productively in a team. Inquiry and cooperative learning strategies improve student achievement and problem-solving abilities more than the lecture format (Cooper, Cox, Nammouz, Case, & Stevens, 2008; Johnson, Johnson, & Smith, 1998; Lou, Abrami, & Spence, 2000; Lou et al., 1996; Schroeder, Scott, Tolson, Huang, & Lee, 2007). The POGIL approach is based on the benefits of inquiry and cooperative learning and that people learn through active involvement in the construction of their knowledge and understanding (Bransford et al., 2000; Farrell, Moog, & Spencer, 1999; Moog, Lewis, & Bunce, 2006).

While POGIL has been implemented and described in a wide variety of chemistry courses, its use in other physical and biological sciences has not yet been described (Farrell et al., 1999; Lewis & Lewis, 2005; Ruder & Hunnicutt, 2008; Straumanis & Simons, 2008; Yezierski et al., 2008). What follows is a brief description of the POGIL approach, a description of its implementation in biomechanics, and a discussion of the challenges and opportunities for an instructor new to this approach. Little of the content of this description will be new to skilled POGIL practitioners, rather it is hoped that this will encourage those unfamiliar with POGIL pedagogy to explore it more fully and to provide a basis for further development of its use in biomechanics and related courses.

Process Oriented Guided Inquiry Learning

POGIL is based on the constructivist theory of learning (Farrell et al., 1999; Spencer, 1999). Major tenets of POGIL are that learning is enhanced when students: 1) are actively engaged, 2) are thinking, 3) analyze data, discuss ideas, draw conclusions, and construct their own knowledge, 4) and are interacting socially (Piaget, 1985). The organization of a POGIL course is also critical to the use of higher order cognitive skills and the development of process skills: 1) there are few, if any, lectures, 2) students work within small groups, 3) students have specific, assigned, rotating roles in their groups, 4) content is mastered by complet-

It is expected that upon completion of KINES 370 that students will be able to:

1. Demonstrate awareness of the scope and practice of biomechanics
2. Describe human movement with appropriate mechanical and anatomical terminology
3. Find and utilize biomechanical literature and reference resources;
4. Understand and integrate kinetics and kinematics
5. Understand, recall, and utilize the qualitative and quantitative relationships between angular and linear motion
6. Apply biomechanical principles to evaluate new/novel information
7. Understand and associate musculoskeletal tissue structure and biomechanical function to the generation of movement
8. Analyze human movement and provide appropriate corrective feedback; and
9. Employ mechanical concepts to optimize movement performance and outcomes

Table 1. KINES 370 Biomechanics course objectives:

ing learning cycle-based guided inquiry activities, 5) the textbook is used as a supplement after the activities are completed in class, and 6) exams are taken individually (Farrell et al., 1999).

Key to the effectiveness of POGIL is the guided inquiry classroom activity. A POGIL activity is built upon the framework of the Learning Cycle (LC), an approach that has been shown to be effective in teaching science (Karplus & Thier, 1967; Lawson, Abraham, & Renner, 1989; Piaget, 1964). The LC as applied here has three distinct stages: 1) Exploration, 2) Concept Invention/Term Introduction, and 3) Application. In practical terms, a POGIL activity starts with a model or set of data that will serve to illustrate key features of the concepts to be presented. The activity requires students to answer questions leading them to explore the model or data. At this stage, students note important relationships in the data or key features of the model. Next, students are asked critical thinking questions leading them to form a generalized concept. Often at this stage, the vocabulary associated with the concept is introduced. Finally, application questions reinforce the concept and further enhance critical and creative thinking skills (Farrell et al., 1999; Hanson & Moog, 2007).

In a POGIL classroom, students work cooperatively in small groups on the guided inquiry activities. To foster the interdependence necessary for successful cooperative learning, POGIL activities are challenging enough that most students find it difficult to complete them independently, but are appropriately targeted so that a group of students can work through them with only targeted intervention from an instructor (Bowen, 2000; Johnson et al., 1998). To aid the group process and to foster individual participation and accountability, roles are assigned to each group member (Farrell et al., 1999; Johnson et al., 1998). The roles used in the biomechanics course were: 1) manager – coordinated the activity and kept the students and group on task, 2) recorder – kept a record of the group's progress and noted key concepts, 3) spokesperson – shared the group's results with other groups or the class in general, and 4) strategy analyst – monitored and commented on group effectiveness and made suggestions to the manager for improvement (Farrell et al., 1999). Roles were rotated daily so that students did not do only what was comfortable, but also developed the distinct skills of all roles (Farrell et al., 1999).

In a POGIL classroom, the instructor's role shifts to one focused on facilitation. This does not mean the instructor uses cooperative learning as a time to relax or work on other things while the students complete assigned kinetics or kinematics problems. Instead, the instructor creates a learner-centered environment, he/she: 1) acts as a consultant to student groups by providing support and guidance, 2) explores what students already know about a topic, 3) asks guiding questions rather than gives answers, 4) encourages students to assess their own learning, and 5) uses class time to create the opportunity for a structured, ongoing conversation with the students about the course material (Bransford et al., 2000; Farrell et al., 1999; Spencer, 1999). If learning, critical thinking and the ability to apply the content are to be improved, students need to be allowed to struggle (Piaget, 1985; Spencer, 1999). Learning is improved when the instructor assists the learners and avoids providing information that the students can generate on their own (Farrell et al., 1999). Having written or chosen a POGIL activity appropriate for the content, the instructor supports the active learning process by allowing students to think about data and models and acts as a facilitator to help the groups stay on track, assist in decision making, provide guidance, maintain class pace and clarify key concepts (Farrell et al., 1999; Johnson & Johnson, 1984; Johnson et al., 1998; Moog et al., 2006; Spencer, 1999). An effective facilitator simultaneously and unobtrusively monitors all groups to insure that they are pursuing the right path. When they are on the right track, positive reinforcement and encouragement are provided. When they are not developing an accurate concept, the instructor questions and guides them back to the correct path while still validating their previous efforts. This means that the instructor has to become adept at asking different questions to help students arrive at the same answer. The facilitator also uses periodic group reporting and facilitator-led summaries to emphasize key concepts and processes to confirm concept clarity and student focus.

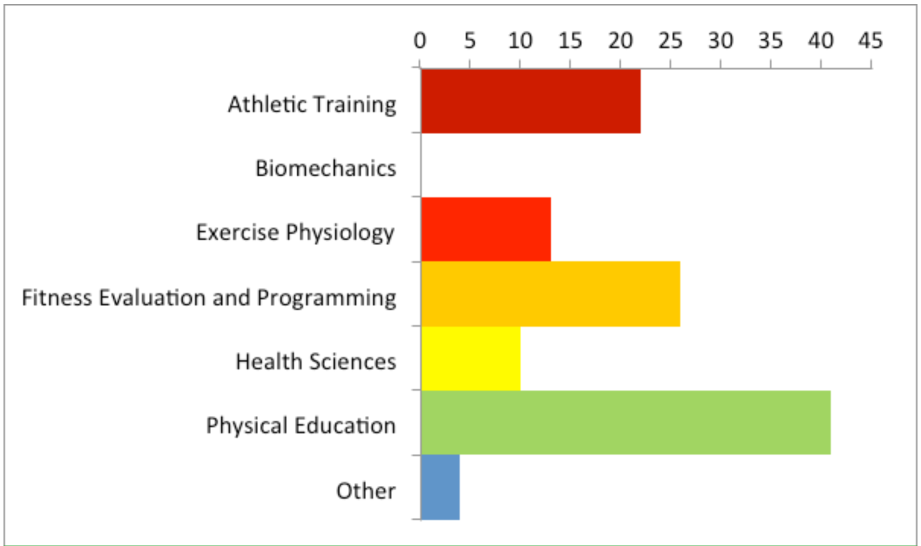


Figure 1. Number of students taking KINES 370 (fall 2007 – spring 2009, n = 116).

Biomechanics at Boise State University

The Kinesiology department at Boise State University offers a two credit junior level biomechanics course (KINES 370) with a one credit lab (KINES 371) which is required of students in degree programs in Athletic Training, Biomechanics, Exercise Physiology, Fitness Evaluation and Programming, and K – 12 Physical Education. Students from the College of Health Sciences also take KINES 370 and 371 to prepare for post-graduate studies in physical or occupational therapy (see Figure 1). The biomechanics class meets for two 50-minute periods each week in a theater style lecture hall. The 110-minute lab meets once per week and is taught by a graduate teaching assistant.

Biomechanics course enrollment is approximately 30 students, ranging from traditional college students to those in their 50s looking to supplement or change careers. The gender distribution is fairly equal with males being slightly more numerous than females. Approximately 25 percent of students belong to a racial or ethnic minority. Less than 10 percent of each class is made up of student athletes. Fewer than 10 percent require special accommodations.

As mentioned previously, this can be a challenging course to teach because of the variety of backgrounds and career goals. There is great diversity in prior knowledge and motivation for learning. Student preparation typically ranges from a year or more of physics and calculus, to no prior physics and only basic college math. Students also range in interest from those who intend to go to graduate school and study biomechanics, to those who plan to enter the workforce with an undergraduate degree to work in the K-12 education system or some other environment.

Lecture was the predominant teaching method used by the first author in KINES 370 for two semesters. Moving to the POGIL approach allowed approximately 90 percent of the course material to be introduced through a POGIL activity.

POGIL Implementation in Biomechanics

Development of POGIL Activities

Perhaps the principle objective of POGIL is that the students interact with the material and form/understand concepts based on models provided by the instructor in the activity. Unlike in chemistry, there are no texts or POGIL materials available for biomechanics – this meant the instructor had to write activities. This development process was labor intensive and challenging, but also helped to clarify the most important learning outcomes for the course and helped the instructor to better understand how students approach the material.

A good model is critical to a well-designed POGIL activity. A POGIL model can be a text explanation, diagram, table, graph, or another format that presents new information to the students. The purpose behind the model is to enable students to explore the characteristics of the model and derive concepts based on what the model illustrates. One recommendation, when transitioning from lecture to POGIL, is to start with the examples that have previously been used in lectures to summarize or illustrate the theories (Spencer, 1999). The activity author then starts by presenting the model and writes questions about the model to help students develop an understanding of the concepts. Unfortunately, prior knowledge is a double-edged sword here, as expertise in biomechanics helps identify good models, but the models, and guiding questions, may not be as clear to the students as they are to the instructor. Initial attempts at POGIL activities provided too much background information in an attempt to be sure students "got it all," resulting in an explanation of the concepts rather than guiding the students to discovery. Eventually, through revision and replacement, a proper balance was found and better models developed, better questions were asked, and the quality of the activities improved. Models and questions were continuously refined for better understanding and future use.

What follows is the description of an excerpt from an activity designed to introduce students to principles of vector resolution. Typically, a lecturer would define scalar and vector quantities and then define speed and displacement. The instructor might do an example problem or two involving vector resolution. Students would be expected to solve analogous problems on the homework. In POGIL biomechanics, students are supported to develop an understanding of these ideas in a markedly different way. First, students are given several diagrams of a swimmer swimming the length (and back) of a pool. Through a series of guiding questions, students first explore the diagrams (e.g., notice the length of the pool and the amount of time it takes the swimmer to swim it). They are thenled to consider the idea of both speed and displacement, at which point the terms are introduced. This is important because while speed is a concept most students understand, connecting it with the idea of displacement is often a challenge. Several more complex diagrams (e.g., a swimmer swimming across a river in which there is a current such that the distance she travels is a diagonal across the river) follow this. At this point, students are introduced to the definitions of scalar and vector quantities and guiding questions prompt students to apply the concepts of distance and displacement for scenarios in the more complex diagrams. The remainder of the activity provides students with increasingly complex vector resolution problems, introducing students to the mathematical strategies they need as they move along, and keeping the focus of the students' work on the application of the concepts of vector addition. The end result is that students have a rich understanding of vectors and the ability to see the relationship between multiple forces acting on an object.

1. Introduction to Kinematics
2. Introduction to Kinetics
3. Mechanical Properties of Bone
4. Articulation Mechanics
5. Muscle Mechanics
6. Mechanics of the Upper Extremity
7. Throwing Mechanics
8. Mechanics of the Lower Extremity
9. Gait Mechanics
10. Mechanics of the Spine
11. Linear Kinematics
12. Angular Kinematics
13. Angular Kinetics
14. Fluid Mechanics

Table 2. POGIL biomechanics activities

Content Coverage

When making the decision to use a cooperative learning approach like POGIL, a common concern is whether the approach can introduce all the material in the course that would have been "covered" in a lecture format. The process of content introduction is often slower and in the implementation described here less material was covered than with lecture format. This change was addressed in two ways: 1) some material was shifted to students to cover outside of class; and 2) other material was eliminated. In previous offerings of the course, much of the first three sessions of biomechanics were a review of terminology, mathematics and basic physics. In order to increase class time available for new material, review guides were developed (terminology lists, mathematical problems, anatomical references, etc.) and assigned as homework. This put the burden on the student and two class sessions were made available that would have been essentially spent providing definitions. Students for whom this material was not review, or who felt their grasp of the material was weak, were encouraged to seek out the math lab, teaching assistant or professor outside of class for additional assistance. This same method for saving time was used again later in the course to review basic muscle and bone anatomy, which freed up another two sessions.

With the assignment of reviews as homework, a small amount of material still had to be eliminated. In order to decide what to cut, the instructor asked "What do I want students to remember, or be able to use, 5 or 10 years from now?" This resulted in an emphasis on movement analysis, because most students in the course would be performing movement analyses on a regular basis in their future careers. It also led to a decreased emphasis on vector algebra and the behavior of materials. These topics are covered in other courses that biomechanics majors must take as part of their degree curriculum.

Reducing the amount of material covered in a basic biomechanics course seems to do a disservice to students. However, even if more material can be "delivered" in a 50-minute lecture, students do not necessarily retain all of the material presented. Studies have shown that students tend to tune out within 10 – 18 minutes of the beginning of a lecture (Johnstone & Percival, 1976). Student inattention lasts a few minutes and repeatedly occurs in increasingly shorter intervals (Johnstone & Percival, 1976; Middendorf & Kalish, 1996). These lapses in attention result in inaccurate recall (Johnstone & Percival, 1976). Thus, the decision to use cooperative learning, which results in higher retention rates, even though less information is covered, made sense (Bowen, 2000; Johnson et al., 1998; Lewis & Lewis, 2005). In addition, this slower, more in-depth POGIL approach made biomechanics seem less daunting and more manageable to the students and helped to address one of the two principle challenges in teaching this course (see introduction).

The topics covered were presented in 14 activities (see Table 2). The philosophy behind choosing these particular topics was to: 1) meet the course objectives (see Table 1) and develop higher order cognitive skills, 2) present the basics of biomechanics (activities 1, 2, 11 – 14; course objectives 2, 4 – 6), and 3) delve into areas applicable to movement analysis (activities 3 – 10; course objectives 2, 8, and 9).

In-class cooperative learning

Cooperative learning, a key tenet of POGIL, requires attention to student group construction (Millis, 2002). Heterogeneous, instructor assigned, groups of four students tend to be the most effective (Lou et al., 1996; Millis, 2002). The use of mixed teams also allows the instructor to address the second major challenge in teaching this course: dealing with the issue of diversity of prior academic preparation. In the POGIL course, students with greater physics knowledge can be grouped with those students who have no physics course work. The physics group can be divided into those who are comfortable with physics (group 1) and those who feel they remember little of the course (group 2). The non-physics students are then divided into those who are comfortable with math (group 3) and those who are not (group 4). Students are asked to self-identify into one of these four groups, directed to line up around the room in group order (1 – 4), and randomly counted off by fours. This results in a relatively even distribution of prior learning. Once student groups are formed, the use of roles, designed to enhance the development of teamwork process skills (Hanson & Moog, 2007; Johnson et al., 1998) can be randomly assigned in (i.e. based on where birth date falls in the year).

Initial groups formed in biomechanics were maintained with a standardized role rotation until the first test. Results from the first test were then used to form new groups to include high and low achieving students in each group (Farrell et al., 1999). Adjustments were also made for observed working styles. This second round of groups tended to be more effective and equivalent to each other in terms of pacing and performance outcomes. Half of the groups were effective and individual student grades were higher on the second test and a good team dynamic was established; no changes were made in these groups for the rest of the semester. The other half of the groups were adjusted after the second test to accommodate observed working styles and interpersonal relationships. Half of these groups continued to have challenges to working effectively – generally because of inconsistent student attendance and individuals who resisted working in a team environment.

Students found POGIL activities required a more coordinated and cooperative approach than they had previously experienced in group work or on worksheets. Initially, many of the groups gravitated toward a completion-oriented approach, did not concern themselves with the process, and initially chose not to follow the POGIL format. They broke down the activities into sections, assigned sections to group members, and agreed to come back and share their answers. Rather than telling the students that they could not do this, they were allowed to try it and determine their own results. They quickly found that unlike a traditional worksheet, breaking a POGIL activity into smaller pieces and finding the right formula or answer in the textbook was not an effective way to complete the work. A well designed POGIL activity builds upon itself as it progresses – each question requires information from previous models and questions – and are designed to be too challenging to be completed by an individual in a timely fashion (Hanson & Moog, 2007; Johnson et al., 1998). Those who took the initial questions had the model and were able to quickly form the concept – completing their share of the work with minimal effort and time. Meanwhile, those who took on the questions later in the activity had no concepts to work from and found the concept invention and application questions difficult, if not impossible, and very time consuming. This struggle and inequality of workload soon led the groups to follow the POGIL structure of the activity, cooperate more, and develop a better understanding of the material.

Another management issue for group work involved dealing with the students who were the most performance-oriented and/or impatient. Performance-oriented students are more concerned about making mistakes than about learning the material (Bransford et al., 2000). These students tended to gloss over, or completely skip, the model and move on to the questions. They are quick to ask questions without stopping to read or study the model. Early in the course, considerable time was spent reminding the students to read, contemplate and discuss prior to asking the instructor for assistance. This was enhanced by following one of the implementation suggestions of POGIL – allowing only one individual from each group, the manager, to ask questions. This required the group to have a consensus about a question before it could be posed. Coming to a consensus often led to others in the group help impatient individuals to slow down and review the model. This allowed the students to find they, or someone else in their group, were able to develop a good approximation of the answer. The frequency declined and the quality of questions improved as students both became accustomed to cooperating and improved their understanding of the design and flow of the models and activities. Despite the expected initial resistance to this new methodology, resistance seemed to decrease as students became more learning oriented and became familiar with POGIL.

Another tool for fostering cooperation, targeting the intended concept, and keeping the group pacing similar, was the use of an ambassador and intergroup consulting (Farrell et al., 1999). This method was effective when one group was quickly grasping the material and getting far ahead of the others, and one or two other groups were struggling and falling far behind. An ambassador from the struggling group was sent to the fast moving group to verify their concept. The two groups then discussed the differences and came to consensus. Occasionally, the instructor provided some feedback if the struggling group member began to sway the other group away from their accurate concept. Nonetheless, the process of intergroup consultation generally aided the group that was having issues by providing another perspective, while encouraging those who had a better understanding to develop a deeper knowledge by explaining the material to another group. This practice also served to keep the groups moving at a similar pace.

A critical component of the implementation of cooperative learning is the focus on student accountability (Bowen, 2000; Millis, 2002; Slavin, 1990). Daily group reports and individual quizzes and test encouraged student accountability for participation in cooperative learning and the learning of key concepts. Student quizzes, tests and homework were reviewed and returned quickly in an effort to enhance student motivation (Cashin, 1979). Further, the daily reports provided by each group were used to ascertain the progress made by each group and to check that key concepts were developed correctly. These reports were briefly reviewed and a simple completion grade assigned for those who participated. Particular components or key concepts were spot-checked to monitor understanding. The next class session was started with a brief instructor-led review to emphasize the key concepts previously developed or to clarify concept formation.

For some students, the use of a completion grade for the daily reports raised concerns. These students shared that a letter grade and an evaluation of their performance is more meaningful than simple credit for completing a task and verifying one or two key components are correct. Students stated that they wanted specific feedback and the opportunity to compare results with others. Discussion around the value of spot-checking, completion grades, and pointing out that feedback was being provided during each class session, unlike a traditional lecture, helped to clarify the use of this tool. Another complication of completion grades was they created confusion when other assignments were graded for accuracy and a numerical or letter grade was assigned. This dichotomy appeared to contribute to the perception that students were being assigned a grade based on effort and completion rather than for quality. Here, an explanation of the difference between formative and summative assessment proved beneficial. It had to be made clear to the students that there are different types of assignments, different expected outcomes and different types of grading (Davis, 1993).

Daily quizzes are used in the POGIL classroom to encourage students to interact with the material between classes, to emphasize key points, to increase individual accountability, and to provide the instructor with feedback regarding students' grasp of the material (Farrell et al., 1999). The biomechanics quizzes consisted of one or two significant questions based on the activities from the previous class. Quizzing the students helped them identify key concepts and provided a guide for test review. The quizzes also appeared to encourage students to look over the material more often than they might in a lecture format. Many students indicated they reviewed the material between classes because they knew they would have a quiz at the beginning of the next class. Students were observed discussing possible quiz questions and correct answers within their groups as they identified what they believed were key points. They were also observed discussing potential questions with each other outside of class time. In addition, when students were allowed to do quiz corrections to earn back half of the points they initially missed, they reported reviewing the material again, improving understanding, and refocusing their efforts. Thus, short, frequent quizzes provided another tool for the instructor to monitor student understanding and further provided an opportunity to address areas that were missed or misunderstood prior to moving on to the next topic. The learning gains associated with the quizzes made it worth the class time needed for their administration.

Students can be initially resistant to this teaching methodology since it is different from their prior experience (Johnson et al., 1998; Millis, 2002). Students who expressed resistance in KINES 370 raised concerns related to two main issues: 1) doing group work, and 2) using critical thinking skills. Some of the high achieving students did not want to do group work as they felt they would be carrying the group and the others would slow them down. A number of the middle level students expressed a common concern that they should be "taught" by the instructor and not by other students (Johnson et al., 1998). A few of the low achieving students felt they would be unable to keep up with the other students. While some students were resistant to group work, others were resistant to the increased energy and thought required by the active learning and critical thinking of POGIL. In other words, those who simply wanted to be told what to memorize for the next test resisted group work.

Resistance was managed in steps. The first step, to address the students who wanted to be taught by the instructor and not by their classmates, was to present an introduction that supports cooperative learning and the theoretical framework of POGIL. Materials available from the POGIL Project describing the research supporting cooperative learning and how it is focused on developing skills sought by employers were presented (Moog et al., 2006). The theoretical framework behind POGIL and how this particular process benefits the students was then shared. These two pieces of information generated enough student willingness to try POGIL. Once they became familiar with POGIL and gained experience with completing the activities, many students were able to see the advertised benefits.

The second step was addressing the student concerns based on their self-perceived achievement level. The high achieving students were encouraged to not only learn the material, but also to work on their cooperative skills, as these would be important in future employment. Many of the students saw the benefit in this and appeared to successfully improve their cooperative skills over the course of the semester. Those in the mid-range of achievement appeared reluctant to take risks and to be wrong about a model. They gave the impression of being paralyzed by the fear of being wrong (i.e., some even to the point of tears) and did not believe that exploring material incorrectly could enhance their learning. Encouraging and reminding them that the most effective life-lessons learned were via mistakes got many through to the point that they were able to experience success with POGIL. Low achieving students (at least those who attended class regularly) quickly bought in to POGIL as they saw they were getting more personal assistance than they would in a lecture format and their quiz and homework scores improved.

POGIL Benefits

Facilitating group work increases and improves instructor-student interactions (Johnson et al., 1998; Millis, 2002). The students and the instructor interact more frequently through instructor observation, answering questions, and providing feedback. This interaction improves the instructor's assessment of the students' grasp of the material via the questions the students ask and how they manipulate the information as they move through the application questions (Millis, 2002). In addition, this type of interaction enhances the instructor's ability to subjectively evaluate students on other skills, such as cooperation and group leadership (Johnson et al., 1998). Student work/learning habits and styles are observed and the POGIL activities and assessments adjusted to better match the students. In turn, student inhibition is decreased and they are more willing to ask clarification questions and to free-think about the material.

By the end of the course, most students indicated the POGIL format provided a positive learning environment (Farrell et al., 1999). The following are representative of biomechanics student comments from the end-of-course evaluation.

> *"I think the format of the class created a better learning environment The transition from the basics to practical learning helped me learn how to*

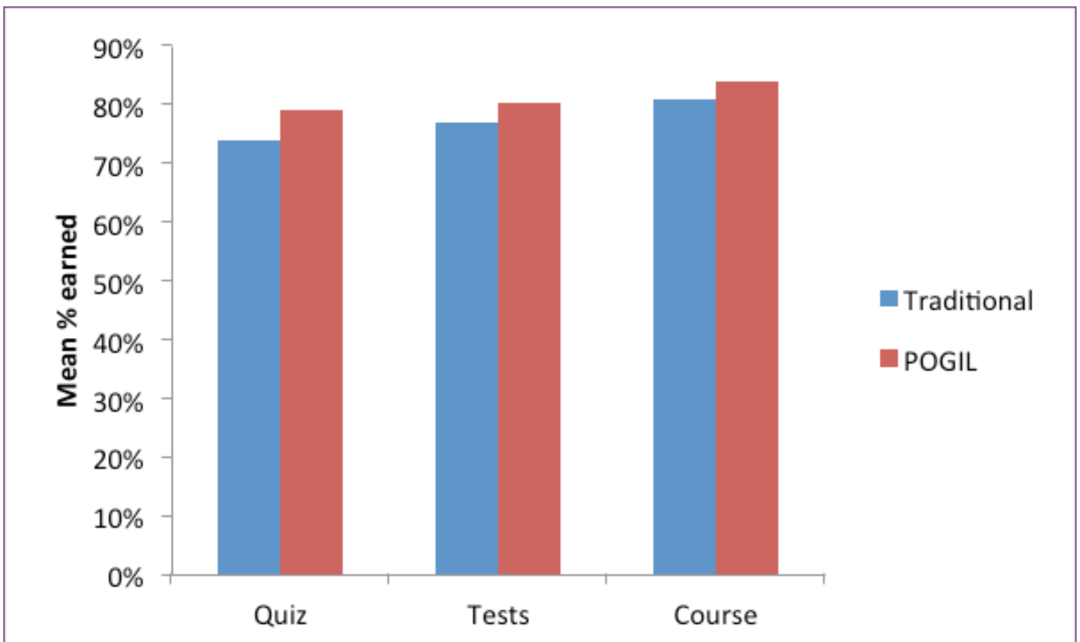


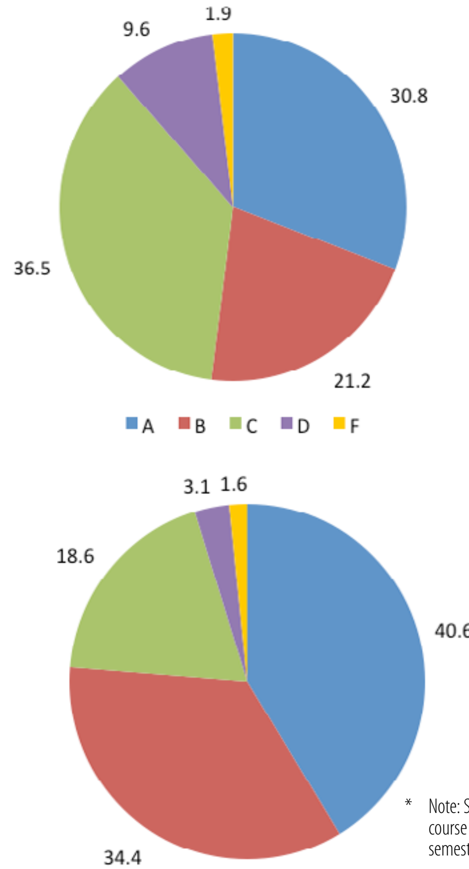
Figure 2. Comparison of assessment results for traditional (n = 52) and POGIL (n = 64) instructional methods.

apply basic biomechanics to activities of daily living and sport."

"I really liked the group work, at first I was a little skeptical about the class being taught this way but in the end I think I was able to better understand the material this way."

"The in class-groups were great because we were able to draw on others for help if needed. It also helped in processing the material by hearing other students' views. (The instructor) wanted us to learn. He also wanted us to do our best and really understand the elements of biomechanics."

While a robust statistical analysis of student performance is not possible for the comparison of POGIL to lecture because of the small number of students involved, there appears to a trend toward improved performance for students in the POGIL course. Mean assessment scores were slightly higher (see Figure 2). Grading was criterion referenced; similar quizzes and tests were used in all four semesters (questions drawn from the text and instructor test banks). The number of A's earned as course grades increased by 10 percent, the percentage of B's by 13 percent, and the fraction of students earning a C was reduced from 36.5 to 18.6 percent, indicating that POGIL may have benefited the mid-level students the most (see Figure 3). The fraction of D students in POGIL was 32 percent of that in traditional lecture and there was a single F in each data set. Those who earned D's and F's typically had poor attendance (this was monitored) and were inconsistent in turning in assignments. Those students who do not regularly attend class do not do well on the assessments nor in the class overall. This seems particularly true when POGIL is utilized and has also been observed by others (Lewis & Lewis, 2005). Overall, these results are consistent with more robust studies done in chemistry and other science courses which demonstrated that cooperative learning was one of the most effective strategies for enhancing student performance and can increase cumulative grades by a median of 14 – 17 percentile points over a traditional lecture format ((Farrell et al., 1999; Lewis & Lewis, 2005; Lou et al., 1996; Ruder & Hunnicutt, 2008; Schroeder et al., 2007; Straumanis & Simons, 2008; Bowen, 2000; Johnson et al., 1998).



a. Percent of students earning a particular letter grade using traditional lecture instruction (n = 52).

b. Percent of students earning a particular letter grade using POGIL instruction (n = 64).

* Note: Students who withdrew from the course within the first two weeks of the semester are not included.

Figure 3. Comparison of grade distributions for lecture and POGIL teaching methods.*

Recommendations

It is the very rare instructor who can effectively utilize any new teaching methodology the first time and not feel that more work needs to be done. POGIL requires a large initial investment of resources – especially when POGIL activities must be written, as was the case for biomechanics. While preparing and refining activities is a labor-intensive process, the time dedicated to these tasks decreases as the instructor continues to teach the course and activities are refined and reused. In addition, as other biomechanics instructors adopt POGIL we can share our activities and reduce each other's workload. Time utilization in and out of the classroom is also changed. More time is spent on a daily basis to review and grade group reports and quizzes. The time spent preparing lectures is eliminated and fewer students seek help during office hours as they are interacting with the instructor and getting questions answered in class. Test and quiz construction time is also reduced as questions and examples can be lifted directly or modified from POGIL activities.

Attention must be paid to small group construction and management to enhance cooperation and foster positive interdependence. Groups of three or four students tend to be more effective when group assignment is diverse and made by the instructor (Johnson, Johnson, Holubec, & Roy, 1984; Lou et al., 1996; Millis, 1991). Heterogeneous and externally formed groups are also more applicable to situations in which students will find themselves outside of the classroom and allows the instructor to account for differences in prior experience and preparation (Millis, 1991). It has also been suggested that positive interdependence and commitment to the group's success can be increased with the mutual goals and interdependent roles as described for this biomechanics class, but also via mutual rewards (Millis, 1991). Millis (1991) suggests creating mutual rewards by using a group grade based on some combination of the individual group members' improvement or grades, adding extra points for group participation and/or performance, or random selection of one group member's grade to assign as the group grade. Individual accountability also improves group cooperation when group members realize that their individual grades depend on how well others in their group do, students are more motivated to aid other group members (Millis, 1991).

KINES 370 was taught in a lecture hall. This was less than ideal, as it was difficult for students to face and create equal distances from each other. A room arrangement that allows desks or tables to be moved and students to face each other is beneficial and facilitates student interactions.

In addition, facilitating cooperative learning is a new skill set to be acquired for most instructors. Instructors have to discover how to interact with the students as they learn rather than directing from a distance. However, the interactions between the student and instructor are more meaningful and worth the extra time and effort.

Thus, the new adopter of POGIL will need to invest time, effort and intention to the implementation of this new teaching style. Progress seemed to occur in exponential increments and the second semester of use was significantly better than the first in that less time was used outside of class and facilitation improved. The utilization of POGIL not only enhances the student-material interaction, but also the instructor-student interaction. The use of POGIL in this biomechanics course was observed to enhance student engagement, knowledge retention, and higher level thinking and application skills and was consistent with the effects of cooperative learning documented in the literature (Johnson et al., 1998; Lewis & Lewis, 2005).

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