Improving Performance through Motivation: Teaching Biology Pre-Med Students Algebra Based Physics. Quantitate Assessment of Different Instructional Methods.

Elena Gregg, Dr.
Department of Engineering, Computer Science, Physics & Mathematics, Oral Roberts University, Tulsa, OK

• Introduction

The National Assessment of Educational Progress (NAEP) and Program for International Student Assessment (PISA) were designed to measure student’s knowledge in mathematics and science (M&S).

65% students performed at or above the Basic achievement level. 28% of students performed at or above the Proficient level. 1% students performed at the Advanced level. Male students scored 5 points higher on average than female.

Results of the science assessment also varied for students of different racial/ethnic groups: White students had higher average scale scores (163 and 162, respectively) than other racial/ethnic groups

As you see from these data teachers in secondary and higher education system have very challenging task. In order to supply fast growing sector of Science and Engineering jobs by quality workers we have to teach M&S in classes with increased number of students of wide range of background and proficiency.

This report points some of the ways in which teaching could help improve student performance and engagement; it also highlights some of the contextual factors which influence learning.

• Teaching approaches and methods.

There is no one correct way of teaching M&S, but different methods can be effectively applied in specific contexts and for particular learning outcomes.

Over the last decade the great majority of states moved towards outcome-oriented curricula, which allows teachers greater autonomy in delivering the set objectives and be more responsive to student’s needs.

Research evidence suggests that effective instruction involves the use of a variety of teaching methods. At the same time, there is general agreement that certain methods such as problem-based learning, exploration, investigation, classroom
organization, using real life context/organize lessons around ‘big ideas’ and interdisciplinary themes, information and communication technology (ICT: I-Pad, I-phone, clickers, Smart boards, etc.) are all effective for raising achievement, improving students attitudes toward M&S, promote active learning and critical thinking through discussions, project work, practical exercises.

**Assessment.** Student assessment is a crucial element of the teaching/learning process and may have variety of forms such as project-, portfolio-, ICT- or self/peer-based. However, research shows that assessment is too often used for grading students, and less for helping them to improve their performance. Two main forms of assessment can be identified: those where results are used for formative purposes, that is to improve future teaching and learning, and those which are used for summative purposes, that is to provide evidence of student achievement over a certain study period.

**Main factors associated with performance:** home background, positive attitudes to subject, self-confidence, gender differences, addressing low achievement, targeted support for students with diverse individual needs, literacy emphasizing the relevance of M&S, and motivation.

The academic literature distinguishes between two motivational concepts – intrinsic and extrinsic. Extrinsically motivated students engage in activities in order to attain external rewards, such as praise from teachers, parents and peers, or to avoid punishment or negative feedback. Students, who are intrinsically motivated, on the other hand, learn for their own interest, enjoyment and pursuit of knowledge and therefore, focus on understanding concepts. Consequently, intrinsic, rather than extrinsic, motivation benefits students the most. Intrinsic motivation leads to self-efficacy, an individual’s beliefs about their own abilities. Studies suggest that particularly in M&S self-efficacy is a clear predictor of student’s academic performance.

**Concepts related to motivation:**
1. Self-concept: how individuals perceive themselves, in this instance as learners, including their sense of self-efficacy;
2. Self-regulation: the capacity to develop learning strategies and resilience;
3. Learner involvement, engagement and participation;
4. Attitudes towards education and learning;
5. Impacts on the learner such as on their self-esteem or through stress and anxiety.

**Motivation and achievement**
It is generally assumed that children learn more effectively when they are interested in what they learn. Moreover, they may achieve more if they enjoy what they learn\[16, 17\]. When students are motivated to learn, they spend more time on tasks, tend to be more persistent in solving problems, take a larger number of M&S courses and choose a career related to M&S\[18\]. Student’s motivation and achievement in M&S may also be influenced by the importance they attach to this subject\[4\].

An important aspect related to motivation and achievement is the impact of student’s attitudes towards M&S. Attitudes are psychological states made up of three components: cognitive, emotional and behavioral. In the context of education, they are seen as personal factors that affect learning\[19\]. Student’s positive attitudes may be enhanced through effective teaching strategies, can promote learning achievement. Negative feelings or anxiety, on the other hand, can become a barrier to achieving good learning outcomes. Anxiety is thus an affective, or emotional, state, which has been shown to impair student performance\[20, 21\].

Another variable related to attitudes which affects motivation is self-belief and self-efficacy. Student’s belief in their own abilities can play an important role in performance and achievement\[22\].

Teaching methods to increase student motivation must be engaging, diversified and connected to student’s everyday life\[4\]. To develop intrinsic motivation, teaching and learning must take place in a supportive learning environment where students are encouraged to communicate their understanding of the tasks and where their ideas are valued and appreciated. Teacher should support students’ self-concept, self-efficacy and enjoyment of the subject as they discuss and share their understanding with peers\[7,15\]. Teachers need to set and communicate high expectations, encourage the active participation of all students, emphasize the value of effort against a certain resignation that success is largely due to inherent ability\[4\].

Gender differences in motivation and achievement.

Although the stereotypical view is that girls and women lack M&S ability, an increasing amount of research provides evidence that males and females differ very little in their achievement\[13\]. However, girls tend to report less positive attitudes, lower levels of interest, enjoyment and confidence in their M&S ability\[22\], have higher levels of anxiety and lower self-belief\[23\], they tend to report lower levels of M&S related self-efficacy\[12\].

Similar results emerge for student’s self-belief, where males tend to have a more positive view of their abilities than do females. Finally, on average, females
experience significantly more feelings of helplessness, anxiety and stress in M&S classes than males and had lower self confidence in their abilities.

The most important finding seems to be that the gender gap is wider with respect to attitudes towards M&S than in actual levels of performance [23].

Overall, it is very important to increase motivation at school, particularly among female students and develop a deeper interest in M&S which could influence their choice of future field of study and career.

• Statistics and research

Based on 7 years (14 semesters) of teaching algebra-based "General Physics" course to pre-med biology majors’ students I accumulated variety of data about student’s motivation and performance.

Pre-med students in average are very motivated about learning. In order to be accepted into Graduate school they have to pass successfully MCAT or other exams required by the school of their choice. Additionally, low GPA will negatively affect their chances. In general, student’s M&S abilities are average or low, but levels of anxiety and stress are very high.

I included into curricula MCAT related questions, used peer instruction method, ICT, and memorization of major formulas. Goals were to develop critical thinking, test-taking skills, practice fast thinking through “mapping” the whole test passage or problem, be able to function under the pressure, and perform calculations without calculator.

In fall 2013 I started to use Enhanced WebAssign® online homework tool to ensure that my students receive interactive problem-solving practice, have access to animations and other visual resources, learn their own way and on their own pace. Enhanced WebAssign®, in my opinion, is not only an assessment tool, it is a learning tool as well, which combine everything what teacher needs: bank of more than 5,000 questions, tutorial problems that offer feedback and hints to guide students to content mastery with solution videos. I like to use it’s animations to explain difficult concepts from the text and visualize phenomena and processes. I was hoping that this new teaching tool will improve student’s understanding and performance.

Several different other assessment methods were used: Quizzes after each chapter, 3 tests, final comprehensive exam in the end of semester and MCAT Practice Test (before and after instructions, similar to Force Concept Inventory idea).
All grades were averaged and tabulated. Separate data were calculated based on gender and racial group. Several sections of same course were evaluated at first separately and then combined to see if there is any difference in performance between small and big group.

- **General Results**

1. **Smaller classes resulted in 5% higher performance** (more interaction with teacher, more engagement, easier to ask questions, more involvement with material). See Fig. 1.

![Graph](image.jpg)

Fig. 1. Plot of mean grade vs number of students in class.

2. **Female students in average had 5% lower grades in Physics.** Result for Physics is in total agreement with national statistics \(^{[1,4]}\)

3. **African-American students in average had 9% lower grades in Physics** with much higher withdrawal and drop-out rate, which is in total agreement with national statistics \(^{[1, 4]}\).

4. **All categories of students in second Semester of Physics performed in average 7% better.** The most academically weak or unprepared students dropped out or failed first semester, those who stayed developed critical thinking, study and test taking skills which helped to improve their overall performance.

5. **After new book/edition was introduced grades drop occurred in Physics (5%).** This shows decreased availability of online resources such as Chegg and
etc. To eliminate this problem I started to use on-line homework/quiz system for all classes.

6. **Implementation of on-line homework gave 7% grade increase.** See Fig. 2, 3. Improvements occurred in all categories of assessments: quizzes, homework, exams, and final exam.

![Fig. 2. Plot of mean grade without and with WebAssign®.](image)

![Fig. 3. Plot of final grades distribution without and with WebAssign®.](image)

**MCAT Practice Test Results.**
In order to increase student’s motivation, since Fall 2010 in addition to implementing MCAT questions in lectures I started to administer MCAT practice exam in the beginning and in the end of the each semester. Overall, 102 students took practice MCAT twice: 58% Females, 42% Males, 16% were African Americans.

Students supposed to answer 52 multiple choice questions (problems and critical thinking) about situation described in several short passages during 60 min session without using calculator. Major formulas and physical constants were given in the text. 0-10 correct answers resulted in MCAT scores “1”, 11-12 - “2”, 13-15 - “3” and so on.

To be just considered for Medical School score should be at least “10” (29 -31 correct answers), score higher than “12” (35 and more correct answers) gives very high probability to be accepted in good Graduate School.

Results in the beginning of the semester gave an average score “2” (11-15 correct answers), nobody had score “10” or higher. After instructions test gave an average score “6” (20-21 correct answers), 12% of the students had score “10” or higher, **83% of students improved their score.**

**Implementation of this additional assessment tool gave 5% grades increase due to motivation improvement.** See Fig. 4.

![Box & Whisker Plot: Grade](image)

**Influence of Peer Instructions on student’s engagement.**
Physics education researchers determined that the traditional lecture-based physics course where students passively absorb information is not an effective way for them to learn. Most students who completed a standard physics class never understand what the laws of physics mean, or how to apply them to real-world situations.

Lecturing is still the dominant teaching method in large classes at the college level, especially in introductory sciences.

In “peer instruction” (PI) approach teacher rather than teaching by telling teaches by questioning. Studies show that this method is a particularly effective way to teach large classes. Teacher expects students to familiarize themselves with the information beforehand so that class time can be spent helping them understand what the information means. To make sure students are prepared, it is possible to has set up a web-based monitoring system where everyone has to submit answers to questions about the reading prior to coming to class. Instructor uses their answers to prepare a set of multiple-choice questions. Usually teacher begins class by giving a brief explanation of a concept he wants students to understand. Then he asks one of the multiple-choice questions. Students get a minute to think about the question on their own and then answer it using a mobile device that sends their answers to instructor’s laptop.

Next, he asks students to talk about the question in small groups. Once the students have discussed the question for a few minutes, teacher instructs them to answer the question again. Many more students choose the right answer after they have talked with their peers.

In Spring 2012 semester I started to use elements of PI. Unfortunately, I did not set up monitoring system to check student’s level of preparedness before class. This was the big mistake because some students still did not read the textbook as they supposed to.

I prepared for each chapter set (3-5) of conceptual questions (multiple choice and/or true/false). During the class each question was introduced twice. First time students used “clicker” individually then they discussed results in small groups and submit answer again. Many more students choose the right answer after they have talked with their peers, were much more engaged and alert during lecture and discussions.

PI method resulted in more than 6% increase in Final grades. 75% of students expressed very high level of satisfaction by it through the Student Opinion Survey. See Fig. 5.
CONCLUSIONS

Several major factors which affect student’s learning need to be addressed:

1. We need constantly analyze and revised curricula of our classes.
2. Apply a range of teaching approaches to meet the needs of all learners.
3. Effectively and with proper feedback use assessment methods.
4. Target low achievement students: to set up appropriate goals and monitor the effectiveness of support programs.
5. Increase student’s motivation and engagement. There is a direct connection between motivation, attitudes, self-confidence and achievement. Students who have positive attitudes and self-confidence usually achieve better results. Achievements are higher among students who perceived M&S as advantageous for their education and career. It is worth connecting M&S teaching with daily life examples. We needed to improve levels of motivation and self-confidence among female students in order to increase their participation in areas of study where M&S knowledge and skills are essential.
REFERENCES


25. Richard R. Hakea, Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses, Department of Physics, Indiana University, 1997