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Studio style of teaching at Rose-Hulman Institute of Technology

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Abstract

The studio mode of teaching has been tried in the three introductory physics classes at Rose-Hulman Institute of Technology. In this mode, students go through both lectures and mini-laboratories almost in every class session. As soon as a theoretical idea is taught, the students perform a related experiment, which verifies the concept. In this method, the traditional laboratories are often broken down into smaller parts, and the students perform these as well as many other mini-experiments, which are normally not taught in the traditional mode. The students are also encouraged to devise ways of improving the experiment to enhance its usefulness in exhibiting the physical principles. In addition, students are often offered extra credit projects where their task is to design an experiment, identify the proper tools, and describe how the proposed experiment will help in the understanding of the related principles. The classes meet for two “periods” at a time, to allow students to finish the class activities for the day. Needless to say, the majority of the students have found this method very effective in understanding some of the difficult concepts in these courses, have shown more than usual enthusiasm in taking part in class activities, and, in general, have retained a positive feeling about the subject matter.

1. Introduction

Rose-Hulman Institute of Technology has incorporated the new studio style of teaching in the introductory physics courses involving Mechanics, Electricity, Magnetism, and Optics[1]. Jack Wilson of Rennselaer Polytechnic Institute (RPI) developed the original idea. At RPI, this method reduced class sizes, increased teacher-student interaction, and enhanced students’ interest in the topic. At Rose-Hulman, the class size is always small, usually not exceeding 30 per section; and the new method received very good feedback from the students as they took a decidedly active part in the classroom. The principle behind this particular style of teaching is that the laboratory is brought into the classroom, and the student tries on hands-on activities regularly to reinforce the concept that has just been introduced by the teacher. The traditional three four-hour laboratory sessions are not present in this format, as the students perform all the experiments during class time. The teacher spends little time at the black board, only just enough to introduce the theory behind the concept. The students work in groups of two or three to carry out the specific activities. The feedback from the students as well as from the instructors who have been involved in this method is very positive, although no hard quantitative assessment data is available yet.

2. Trials of studio physics at Rose-Hulman

a. The first trial

The studio style of teaching at Rose-Hulman was first introduced in the introductory mechanics course in physics. This was a trial to test how well the students at Rose-Hulman liked this method, and how much they would benefit from this mode of teaching. The entire class was divided into three sections, with about 28 students in each. One of the sections was taught in the traditional way, and the other two in the studio format. At this time, all the freshmen had laptop computers; the students were given the option of choosing their particular section, those with laptops were encouraged to go into the studio sections. The topics covered in the three sections were identical, and the same final examination was given to all the three sections at the end of the quarter. The final examination was cross-graded by all the three instructors. This lessened any chance of an individual instructor’s partial grading, and ensured a direct method of comparison between the student performance from the two methods of teaching.

The studio classes met for two hours at a time, for two days a week in a laboratory room, and for one hour once a week in a regular classroom. The classroom where the one-hour sessions met, had network connections, and a projection system for the instructor’s computer screen to be viewed by everyone in the class. This session was meant to wrap up the week, as well as to do some problem solving, sometimes using Maple software and Working Model simulations.

The two-hour studio sessions were taught in the original laboratory rooms. These rooms had chairs at the front, where the students could sit in front of a black board to listen to the lecture part, and then could move to the back of the room to their laboratory stations when they performed the different “activities”. Several small, but useful experiments were devised to reinforce the concepts introduced. For example, when the concept of friction came up, video recordings were made of a block of wood sliding down an incline. Later, the students analyzed the video frame-by-frame, with Vidshell software[3], to find out the coefficient of friction. The students were not given any particular instructions as to how to achieve that. Some of the students used the concept of conservation of energy to arrive at the coefficient value, and some others used the free-body diagrams, along with Newton’s second law to obtain that value. There were many such small activities where the students were taught the underlying principle, but were left alone to come up with the required answer. The instructor acted as a guide to lead them through the different hurdles, but did not give them the entire solutions. On the whole, the instructors found that compared to traditional classes, the students learned some difficult concepts more effectively through these activities, and they even devised ways to employ some of the earlier concepts to arrive at the results. This method also made them more comfortable in a team environment, and most of the students enjoyed it.

The original laboratory experiments were often broken up into smaller parts, so that the students could finish them in one session. Care was taken that these “mini” experiments were *in-sync* with the class lectures, which the traditional class could not always guarantee. The students were required to have a laboratory notebook, where they took the data for all the activities. At the end of a few weeks, the students were required to turn in a report, which would include results and discussions from several activities. Four of these major reports were collected during the entire quarter, and each student was required to be the principal investigator for two of these. One of the studio instructors, Dr. Daniel Hatten required his students to submit the reports electronically, and graded and sent them back to the students electronically. One of the authors, SMK, was the other studio instructor, who asked her students to submit paper versions of typed reports. Both the ways worked very well, and there were no unusual problems.

b. The later trials

The next times studio physics was taught at Rose-Hulman was when the department had already switched to the format of Physics I, II, and III, instead of the former Mechanics, Waves, and Electricity and Magnetism. All the engineering majors are now required to take at least Physics I, and II, and most of the majors Physics III. Physics I covers mostly mechanics, Physics II some mechanics, particularly, circular motion, and electricity, and Physics III magnetism, optics, and a small portion of special relativity. Generally students take Physics I in the fall quarter, Physics II in the winter quarter, and Physics III in the spring quarter. In the spring quarter of 1997-98, all the seven sections of Physics III were taught in the studio mode. This was a little overwhelming with packed schedules and back-to-back classes in the same room. Later, the department decided to go with the studio mode when the number of students taking these courses is smaller. In the winter quarter of 1998-99 all the three sections of Physics I, in spring quarter of 1998-99 both the sections of Physics II, and in the fall quarter of 1999-2000 all the three sections of Physics III were taught in the studio mode. The experiment with the studio format is still continuing to gather sufficient data before a final decision can be made as to whether the studio mode is going to be adopted for all the introductory physics courses during the entire academic year.

During the quarter when all seven sections of Physics III were taught in the studio mode, five instructors were involved in the teaching of these classes. One particular laboratory room was designated for the entire quarter for the teaching of these classes. The room was equipped with network connections, as well as with projection facility for the instructor’s computer screen. Some minor additions were made such as the installation of white boards and screens, and more comfortable chairs were placed around the podium for the lecturing part. In the later trials, the classes are being taught in a regular classroom equipped with network connections and projection facilities. This classroom also has storage space for equipment. In these later trails, the students occasionally use laboratory rooms for more elaborate experiments.

Starting with the second trial of studio, all the sections of studio physics meet three times a week, for two-hours each time. Care is taken to put back the equipment, and keep the room in order for the next instructor. Also, in order to match the number of hours with any traditional introductory physics classes, which have five three-hour laboratory sessions, and thirty-six one-hour lecture sessions during the entire quarter, the studio sections are given ten hours off from their schedule.

Similar to the first time, the students are exposed to a number of different activities. Quizzes are given on a regular basis. These quizzes were often based on the results from a previous activity. The students seem to attend classes more regularly, probably partly because of their enthusiasm in the topic, and partly because of the fear of missing some important activity. Also, the role of computer software plays a significant part in these classes. Students are encouraged to *visualize* the solution they arrive at for any given problem. To this end, programs like Working Model (WM), and Excel are extensively employed. Even for the simple 1-D motion problems, Excel is used in situations where displacement is not a simple function of time. This helps students in understanding the general relationship between these quantities. Another useful use for Excel is to start with a standard problem in 1-D or 2-D motion and then “evolve” the problem in stages. Students are asked to examine trajectories for a given set of conditions. Examining the solution in the presence of friction then modified the problem. The friction model used could also be changed to show the effects of drag force more clearly. Students could then be asked to check their results against simulations provided by WM. This approach of relating simple problems to harder ones by using graphs and simulations help illustrate the general principles that are at work. Students tend to think of topics as more connected instead of compartmentalizing their physics knowledge in terms of chapters in their text.

One of the authors (MMS) encouraged the students in his class to submit a proposal for an experiment of their own. The idea is that the students have to write a detailed report where they start out by explaining the principle they hope to verify with their proposed experiment. At this stage, they are required to seek some feedback from the instructor and their peers The next stage involves designing the details of the experiment This could involve existing experimental setup or they could work with the machine shop to design simple parts. Also, they could look into the possibility of particular simple components. The next stage is to construct the prototype, and the final stage is to demonstrate that the experimental setup meets its stated objectives. A simple example of this was an Atwood’s machine type of an experiment using smart pulleys. This would be helpful to the students, since the only experiment in the syllabus that currently uses smart pulleys is a simple pendulum experiment.

One aspect that needs to be addressed carefully for projects like the one mentioned above is the nature of the projects and the selection of the students who undertake these projects. Often the students showed a lot of enthusiasm at the beginning, but quickly found out that the projects take too much time, even when they are substituted for one or two in-class exams. It is imperative that the project is not too long drawn, and that a timeline is established, so that the students do not neglect these projects till the end of the term. Further trials will be made with this idea, since, among other advantages, this method will help establish a channel where students keep injecting fresh ideas into the syllabus, as well as leave their mark on the syllabi for classes to come.

3. Some specific activities

Since the driving force behind studio is hands-on work, a lot of time is spent in carrying out small activities. Students are encouraged to model any problem that could lend itself easily to such a process in terms of required materials. One such example would be that of two masses connected with a thread, where one mass executes circular motion on a horizontal plane, and the other is vertically suspended below. Problems like these also open students' eyes to the real life complications that arise when all the textbook assumptions such as ideal connection and no friction cannot be enforced. For some students it can lead to independent learning so they can better understand the problem. For most students it is, at the very minimum, valuable to see how their models differ from the idealized model of the theory and what steps are involved in making their model approximate the ideal one.

Another example of a mechanics activity, besides the ones mentioned above, involve the projectile motion of a steel ball. The students launch a small steel ball at an angle to the horizontal by means of a spring-loaded launcher, obtained from Pasco Scientific. They have to do some preliminary experiments to find out the speed of the ball when the ball is shot at a particular spring setting. After that, the students predict the horizontal range of the projectile, and place a small cardboard box at that position to verify the theory. They also find the highest point of the projectile motion, and place a hoop at that height to verify the theoretical value. They later discuss any errors that may have crept up in their experiments. Another similar activity involves taking a video of the projectile motion of a Ping-Pong ball, and analyzing the video frame-by-frame with the help of a software[3]. They transfer the data to Excel, and discuss the buoyant and drag forces, and the predicted range and the highest point reached by the ball.

One activity involving the concepts of rotational kinetic energy and moments of inertia is as follows. One end of a meter stick is attached to a string, which passes over a pulley at the end of a table, and a small mass hangs freely from the other end of the string. The free end of the stick is made to slide across the vertical wall next to the table, with a pencil attached to that end. When the front end of the stick slides across the table, the pencil at the other end makes a mark on a piece of paper on the wall, and one can exactly find out at what point that end loses contact with the wall. The pulley is attached to a shaft encoder, which takes the data on a computer[4]. The computer gives a graph of angular displacement as a function of time, from which the students find the angular velocity. The students then compare this value with the theoretical value of the same quantity.

Some of the activities in magnetism include electron-beam deflection between two Helmholtz coils where the student finds the e/m ration of an electron, maps the magnetic field inside a current-carrying coil[4], determines the force on a current carrying wire, and many others. The somewhat abstract nature of the concept of "magnetic fields" becomes more understandable to the students with the help of these various activities. The students take an active part in the activities, and ponder over some difficult experiments. For the coil activity, the students send some current through a metallic slinky, and with the help of a magnetic probe and appropriate software[4], they can ascertain the relative strength of the magnetic field inside and outside the coils. They also test the same idea with tightly wound coils of different length to diameter ratio, and understand the concept of an ideal solenoid. With some simple exercises with different shapes made with pieces of paper they can grasp the idea of electric or magnetic flux more easily.

The optics activities are very popular with the students. The concepts of Law of Malus, polarization by reflection and refraction, total internal reflection, and many such concepts are more clearly understood with the help of the various related activities. These topics are not generally covered in the laboratory part of the traditional course. In particular, while demonstrating the Law of Malus, the students shine a laser beam through two polarizers, which have calibrated angles for measurement at different orientations, and are mounted on an optical bench. The students change the relative orientations between the two polarizers, and measure the intensity of the final beam with the help of homemade light detectors.

4. Overall outcome

From the first attempt of studio teaching, it was found that there was a distinct difference in the student performance between the studio and the non-studio classes. The students from the studio classes performed much better than the other class in the final examination, scoring, on the average, about 15% higher than the non-studio students. The evaluations from the students were very encouraging, and most of the students found this new method more enjoyable, less monotonous, and more fun. This new method seemed to build their team spirit, and helped them develop problem-solving techniques.

The class-room/laboratory environment proves to be friendlier for the students. Discussions on the topics are initiated readily, and even the shy students open up after a few classes. The instructors get to know the students individually in only a few days' time, and the atmosphere is much more relaxed than the traditional class atmosphere. The end-of-the-term evaluations have indicated that, overall, the students find the class activities helping them develop a clear understanding of the course material. Majority of the students stated that the small group arrangement is not only helpful in learning the material and solving problems, but also in enhancing interpersonal communication skills. There have been no hard quantitative assessment results from this method. However, feedback from the students' evaluations has been very positive. Some students have sent e-mail messages to some instructors at the end of the quarter saying how much he/she enjoyed the studio experience. There are a few complaints, but nothing definite on any particular issue. Some students, for example, have complained that the activity part is too much, whereas some others have complained that the lecture part is too overwhelming. It seems that, in general, the studio format suits best for those students who are not intimidated by the idea of some independent thinking. Also, the notion of being more involved in their learning is, for most students, a welcome change.

The instructors who have taught the courses also have found the experience very effective. They get to know the students more personally, and can attend to their specific difficulties more readily, and on an individual basis. The atmosphere in the classes is very friendly, and the students open up to questions and suggestions more readily. The performance from the students is very adequate, which is very gratifying for the instructors. Needless to say, the instructors welcome the refreshing change from the traditional atmosphere where the majority of the students are inactive and reticent to ask questions. As mentioned earlier, the experiment with the studio format is still under way, and there is a possibility that all the three introductory physics courses at Rose-Hulman will be all taught in this mode.

Bibliography:

1. “Thoughts on Studio Physics Approach”, S. Mitra-Kirtley, Optics and Photonics News, September, 1998.
2. "The CUPLE Physics Studio," The Physics Teacher, Vol. 32, p. 518, December 1994.
3. Dr. Doyle V. Davis of New Hampshire Technical College developed the software.
4. Dr. Michael J. Moloney of Rose-Hulman Institute of Technology developed a number of experiments, and wrote the necessary computer software for data acquisition.

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