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AUTHOR Brekke, Stewart E.
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ABSTRACT

This paper reviews recent literature in order to identify factors affecting student performance in introductory high school and college physics courses. An important factor identified was formation of cognitive structures such as formation of problem solving schemata. It was concluded that Piagetian concepts such as concrete and abstract reasoning are not as important as visual-spatial abilities, induced cognitive structures of sex roles, and external factors such as teaching style and, to some degree, curriculum. Contains 19 references. (JRH)

SOME FACTORS AFFECTING STUDENT PERFORMANCE IN PHYSICS

Stewart E. Brekke

Northern Illinois University

Question: What are some factors affecting student performance in introductory high school and college physics courses?

Physics at any level is thought of as a hard subject. Problems in passing physics in high schools, as an undergraduate or as a graduate student are common. Very often, passing a physics course means mastering the required problem solving techniques and solving problems of the course (Wright & Williams, 1986). One of the more common view of professionals in physics and non-professionals is that the mathematics used to solve physics problems makes the physics hard. Recent research, however, has shown that a physics problem is not treated like a math problem. Rather, it is the combination of qualitative aspects of physics problems combined with quantitative aspects of a physics problem and the qualitative aspects are more difficult to learn. The research pointed out that there are both concrete and abstract aspects to a physics problem which create difficulties for the learner (Tobias, 1988). While prior mathematical knowledge is a predictor of performance in introductory college physics, Hudson and Rottman, (1981) suggested that there are other factors in the completion of the course. Hudson and McIntire (1977) have pointed out that their studies show highly motivated students can overcome deficiencies in prerequisite mathematics and successfully complete an introductory college physics course. This conclusion, however, is based on a small sample.

One approach to the prediction of success in solving physics problems, thereby passing the course, is to deal with cognitive structures of introductory physics students. Chietal (1981) determined that expert problem solvers in physics had differently organized knowledge bases than novices. It appears that experts tend to sort problems according to the underlying physics principles and novices in contrast attended to the surface characteristics of the problem situations. From this information and other studies, they inferred that the knowledge of an expert is structured differently than novices. The experts possess more complete and adequate problem schemata. They defined a problem schemata as a "set of elements of knowledge that are closely linked with each other within the knowledge base of the problem solver and that concern of a particular type of problem." (de Jong & Ferguson-Hessler, 1986). De Jong and Ferguson-Hessler (1986) have gone further, however, and maintain that the content of an adequate problem schema in memory is not limited to solution principles. There must be declarative knowledge such as principles, formulae and concepts, but also a problem schema should also contain characteristics of problem situations so that a connection between an actual problem and the problem schema is possible as suggested by Shoenfeld & Hermann (1982). It should also be pointed out that Reif & Heller (1982) have taken another approach and suggest that the knowledge of experts is organized in hierarchical fashion, and this means that their knowledge is arranged on different levels of detail so that the higher levels give abstract and general laws and definitions which are manifested and specified at the lower levels. De Jong and Ferguson-Hessler (1986) tested novice and expert problem solvers and found there is support for the Hypothesis that novice problem solvers have their knowledge organized in a more problem-type centered way than poor problem solvers. Once a student recognizes the relevant characteristics in the description of the problem, the declarative and procedural knowledge needed for the solution become available assuming the student has a basic knowledge of the physics and required mathematics.

A decade ago there was interest in Piagetian techniques which contrasted the abstract and concrete reasoners and techniques for changing the reasoning patterns of students in physics classes in college from concrete to abstract (Dukes & Strauch, 1984). At present, interest in Piaget and abstract and concrete reasoners has declined, but the research remains. There are different developmental levels of cognitive ability among college students in introductory physics as determined by Piaget's measures and in one study, over half the subjects did not appear to be at a formal operational level (Cohen, Hillman & Agne, 1978). Elkind (1962) found that only 58% of 240 college students could conserve volume, an ability Piaget theorizes occurs at the onset of formal operations and McKinnon and Renner (1971) found that about 50% of their sample of college freshmen could be classified as concrete operational, approximately 25% were between formal and concrete levels, while only about 25% were considered to be formal operational thinkers. However, later research showed little correlation between Piagetian level and final course grade, and the best predictor of success in college introductory physics was the SAT mathematics score (Cohen, Hillman & Agne, 1978). Thus, the researchers concluded that restructuring introductory college physics courses to meet Piagetian cognitive criteria was unnecessary.

In another study, it was demonstrated by Pallrand and Seber (1984) that the visual-spatial scores of liberal art students were lower than those of physics majors, and that the students who dropped the course in physics tested the same on a mathematics skills test as those who successfully completed the course. This was taken to indicate that spatial ability is a factor in physics achievement. Students who withdrew tested lower in spatial ability, and that those who take physics courses, improve visual-spatial ability. The authors also referred to the classic study of Ann Roe (1952) that of the 64 eminent scientists studied, all possessed the ability to conceptualize visually at unusually abstract levels. Also, Siemankowski and McKnight (1972) found that science students, especially physics majors, possess more highly developed visualization skills than non-science students, indicating that the spatial visualization factor may be important in success in physics courses.

While the above studies make no distinction in gender, the fact remains that fewer females take physics in high school and in college. This points to a mindset which affects success in physics courses. My personal observations of physics and physical science classes in our high school, indicate that the boys do better than the girls and that the girls seem to avoid the laboratory work - especially in the lower level classes. Sells (1978) found that 57% of entering males of one college class had taken the fourth year of high school math while only 8% of entering females had done the same. Also, Sells reported that the women students especially did not feel they were prepared to take courses in calculus, physics and engineering. Tobias (1985) reported that many women students do not feel they have a mathematical mind and simply avoid courses such as mathematics and physics. Thus, many young women have developed cognitive structures which make them poor physics students since one must have a "mathematical mind" to be successful in physics problem solving. This contention is supported by work done by Ehindro (1986) on a Nigerian physics student population. In the study, it was determined that the interaction of sex-role stereotyped expectations and achievement were significant and that the lower expectations of the female students correlated with lower performance. Howe & Shayer (1981) had findings which further support this conclusion reporting sex-related differences on initial performance in favor of boys ten and 11 years old on a Piaget-related task of volume and density. They also allowed for the girls to interact with appropriate materials and with each other, however the girls did not catch with the boys. Thus, the cognitive structures women develop in youth may affect expectations which affect performance in physics.

The curriculum and teaching may have an effect on student performance in introductory college physics and on high school physics. Despite the fact that high school students who take physics are generally exceptional as a group, tending to have high grade point averages, to perform well on standardized tests and tend to rank high in mathematical ability (Porter & Czujko, 1986), institutional, cultural and social factors affect a student's decision to take physics in high school. For instance, at Robeson High School in Chicago, simply a neighborhood school which all types of students attend, every student must take four years of science and four years of mathematics which includes physics. While good students generally will do well in most circumstances, when students of different learning styles and background are in high school physics, the teaching or the curriculum can become important in student success.

Many high school students have difficulty learning high school physics and Idar and Ganiel (1985) developed a remedial teaching method consisting of immediate and frequent feedback in a natural classroom setting. This method resulted in significantly higher achievement indicating that teaching method remains a factor in successful problem solving and therefore, success in high school physics. Supporting this research is the work of Halloun and Hesterenes (1987) who contend that the poor performance typical of most students in introductory college physics courses suggest that conventional methods for teaching problem solving are far from optimal. By contrasting the traditional lecture method to the dialectical large diagnostic test gains of low competence students and gains in test performance in the course were found. Minstrell (1984) has shown that the intensive dialectical method has resulted in success in teaching Newtonian mechanics. Wright and Williams (1986) found that a problem solving strategy (WISE) increased student and instructor perceptions of accuracy and promoted organization as well as performance. Although the greatest success of the WISE method was with those who had high math skills, students with low mathematics skills also showed improved performance.

The curricular aspect of a physics course may determine if a student passes or fails. After renewed interest in science courses at all levels due to Sputnik, two new courses were developed for high schools. PSSC Physics was an upgrading of the high school course with a view toward training future scientists and emphasized student observations and conclusions based on experimental evidence. Project Physics was more humanistically oriented and aimed at increasing physics enrollments at high school. PSSC was primarily a laboratory centered course, while Project Physics aimed at p[people interested in history, languages, music and so on. Later, courses were developed such as the PSI based on individualized instruction Pallrand & Lidenfield (1985).

While the PSSC and Project physics have had their impact on contemporary high school physics course, both courses have not succeeded in becoming adopted. In a nationwide survey by the Educational Testing Service, approximately 9% of United States High Schools used PSSC, 30-40% used Project Physics and the conventional course using *Modern Physics* as a text, was adopted by about 54%. Since passing a physics course is a test of problem solving in physics, it should be noted that an ETS survey of 1981 showed that there is no great difference between students who had taken different kinds of courses (Pallrand and Lidenfield, 1985). The basis for this conclusion is the College Board Physics Achievement Tests. The average for students who had taken the PSSC course was consistently higher by a small amount, but it is not certain if the difference was due to the course or to student selection since the PSSC is usuallly reserved for the better students. A survey taken by the American Institute of Physics found that 25% of those who earned bachelor degrees in 1983-1984, took PSSC physics in high school, and 12% took Project Physics (Pallrand & Lindenfield). Since problem solving in physics is a measure of who will pass a physics course, it appears that the type of course i.e., traditional, PSSC, or Project Physics has little bearing.

In conclusion, factors which may affect success in high school or introductory college physics, typically including cognitive structure such as formation of problem solving schemata. It appears that Piagetian concepts such as concrete and abstract reasoning are not as important as visual-spatial abilities, induced cognitive structures of sex roles, and external factors such as teaching style and, to some degree, curriculum. There is evidence that all are important in passing a physics course as measured by problem solving of physics problems.

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