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ABSTRACT

This paper reports a study designed to examine the types of behaviors students exhibit while conducting laboratory activities and assess the effectiveness of strategies students employ. The sample was 42 students enrolled in a physics lab section at a single university. Three types of data were collected: (1) observational data during the lab sessions, (2) interviews, and (3) written assignments. The data collected through the observations revealed five different categories of strategies: integration, completion-of-task, calculation, observation, and social interactions. Integration was defined as the group of strategies that students used in attempting to relate the laboratory task to theory or prior knowledge. Task completion is the set of strategies used to get through the various tasks to collect data. Calculations referred to finding and using mathematical formulae. Observation contained two strategies: selective attention and data verification. The last category, social interactions, contained two sub-categories: task distribution and disagreement resolution. (PR)

Strategies and Skills Exhibited by College Students During Laboratories in First Year Physics

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Strategies and Skills Exhibited by College Students

During Laboratories in First Year Physics

"If people do not recognize the existence of a problem one cannot expect them to look for a solution." (Bransford, Sherwood, Vye, & Reiser, 1986, p.1082)

Strategies are procedures through which individuals purposefully complete learning tasks or overcome perceived learning difficulties. For example, in completing a reading task, an individual may select a rereading strategy if a section of text was not fully understood after the first reading (Garner, 1987). Or, in solving a mathematical or physics word-problem, an individual may use a categorization strategy in which he/she categorizes the problem type prior to initial attempts to solve it (Bowen, 1990). Strategies generally take time to develop, however, if used frequently can become automatic. Individuals' abilities to employ cognitive strategies, and simultaneously to critique their degree of cognitive processing in order to recognize problems, are critical for learning to occur. This is true whether the individuals are trying to comprehend a bit of textual information, to solve a mathematical word-problem, or to complete a science lab (Rohwer & Thomas, 1989).

Labs have been included as part of science classroom activities for many decades. For the past 20 years, the focus of much of the research examining school science laboratory activities has been on: (a) comparing two lab formats on students' achievement, (b) surveying students' attitudes toward lab, or (c) comparing the way novices and experts solve problems (Howe & Barden, 1991). Only a small number of studies have been conducted to examine the types of cognitive and metacognitive skills and strategies students tend to employ while conducting a lab in a classroom setting (Schauble, Klopfer, & Raghavan, 1991).

The processes individuals use in solving problems have been critically studied in recent years (Rohwer & Thomas, 1989). Much of the recent research concerning problem solving has focused on comparisons between the ways experts and novices go about solving particular kinds of problems, usually word problems, or between the ways more and less successful novices go about solving those same problems. The results of this line of research have revealed that novices tend to use surface structures of a problem when attempting to solve it, while experts, and successful novices, tend to use deep structures of the problem in the problem solving process (Bowen, 1990; Hardiman, Dufresne, & Mestre 1989; deJong & Ferguson-Hessler, 1986; Mestre, et al., 1993). However, the research has focused on individual efforts, not group efforts. The school science laboratory tends to be conducted within a social environment, with two to four students working together to complete a lab activity. Since the school science laboratory is a social environment, the types of cognitive and metacognitive skills and strategies used may differ from those found during the solving of problems individually (Holliday, 1992; O'Laughlin, 1992). Even less research has assessed possible correlations between students' use of specific skills and strategies and their levels of understanding scientific concepts.

The purposes of this study were: (a) to systematically examine the types of behaviors students exhibit while conducting laboratory activities, (b) to develop a coding scheme to better examine the strategies students use in completing laboratory tasks, and (c) to assess the effectiveness of the strategies students employ. This study is still in progress. Therefore, this paper will focus primarily on the first two purposes.

Methodology

Subjects

The target population for this study included college students enrolled in an introductory level science course. The sample was delimited to include 42 students enrolled in one of four physics lab sections at a single university. Two of the four lab sections corresponded with the physics majors nonhonor (i.e. regular) physics course and the other two corresponded with the physics majors honor course. Because of scheduling problems, the four lab sections met at one of only two times in the same lab room on Friday afternoons. The earlier lab session included 8 students enrolled the honor lab section and 15 enrolled in the regular lab section while the later lab session consisted of 9 students enrolled in the honor lab section and 10 enrolled in the regular lab section. A single lab teaching assistant taught all four lab sections.

Materials

Fourteen laboratory activities were developed for the two lab courses. However, the first lab was designed to familiarize subjects with the computer and the specific program they would be using during the semester (i.e. Quattro), so was not used during this study. All remaining thirteen labs used during this experiment were designed in a traditional manner. They provided subjects with the objectives to be accomplished, a description of the theoretical basis of the lab, a number of content-based pre- and postlab questions, and a series of step-by-step procedures. The intent of the labs was to confirm content presented in the lecture portion of the course or to familiarize students with specific pieces of apparatus. Five of the 13 labs were designed to be conducted by all four lab sections. Of the remaining eight labs, four were designed for the individuals enrolled in the regular lab sections and four for those enrolled in the honor lab sections. The lab topics included: force and vector analysis (r2 & h2[1]), acceleration of gravity (r3 & h3), conservation of mechanical energy (r4 & h4), motion on an inclined track (r5), friction (r6), projectile motion (r7), conservation of linear momentum (r8 & h5), inertia balance (r9), centripetal force (r10 & h6), simple harmonic motion (h7), thermal expansion and heat of fusion (h8), Boyle's law (h9), and standing waves (h10).

For each lab, copies were made of each subject's responses to the pre- and postlab questions and final lab write-up.

A semi-structured interview was developed in order to further examine subjects' use of strategies. The interview protocol was developed to focus on four components: (a)

[1] "r" will designate the regular lab section and "h" will designate the honor lab section. The number following the letter designates the placement of the lab in sequence. For example, r2 designates that the lab was the second lab conducted by the regular lab sections.

preparation for lab, (b) activities during lab, (c) completion of the lab report, and (d) lab content. All interviews were audiotaped for later transcription.

Procedure

During the fourteen week semester, subjects conducted ten different laboratory activities. The lab sequence was established so that the labs conducted during the first four meetings were identical for the honor and the regular lab sections. During the remaining six lab sessions, subjects in the regular sections performed different labs, or labs at different times, than those in the honor sections. The first laboratory activity for the semester was designed to familiarize subjects with the computer and the specific program they would be using during the semester. Therefore, it was not counted among the thirteen labs listed above and no data were collected during that lab session. Data were collected during the remaining nine lab sessions.

Three distinctively different types of data were collected during this study: (a) observational data during the lab sessions, (b) interviews, and (c) written assignments. The procedures for collecting each of these data types will be described in the following paragraphs. Prior to collecting data, subjects selected a lab partner with whom to work for the remainder of the semester. Only in cases where an individual dropped the course did lab partners change.

Observational Data. During the lab period, lab pairs were observed for between five and twenty minutes. The length of time each group was observed during a particular lab period was partly dependent upon the lab. Each lab consisted of several parts. Each group observed during a particular lab session was observed for the duration of at least one part. For example, the second lab required subjects to experimentally determine the resultant vector for several problems. Each separate problem was considered a separate part of the lab. Therefore, each group observed during that lab was observed for the duration of solving at least one problem. The data collected included: (a) audiotapes of the subjects conversations with one another and with the instructor and (b) field notes. The field notes focused primarily upon the following: (a) subject-subject and subject-instructor interactions, (b) subjects' manipulations of the equipment, and (c) subjects' reference to texts, including, but not restricted to, the lab manual, course text, and course notes. The order in which groups were observed was randomly determined.

Interview Protocols. Twelve subjects volunteered to participate in a semi-structured interview. The interviews were conducted individually outside of class or lab time. Each interview lasted from 20 to 30 minutes depending upon the depth of subject's responses. The audiotapes are currently being transcribed and analyzed.

Written Assignments. During the course of the semester, subjects submitted a number of written assignments including pre- and postlab questions and lab reports. A copy was made of each of these assignments. In addition, the grades for each of these assignments was obtained from the course instructor.

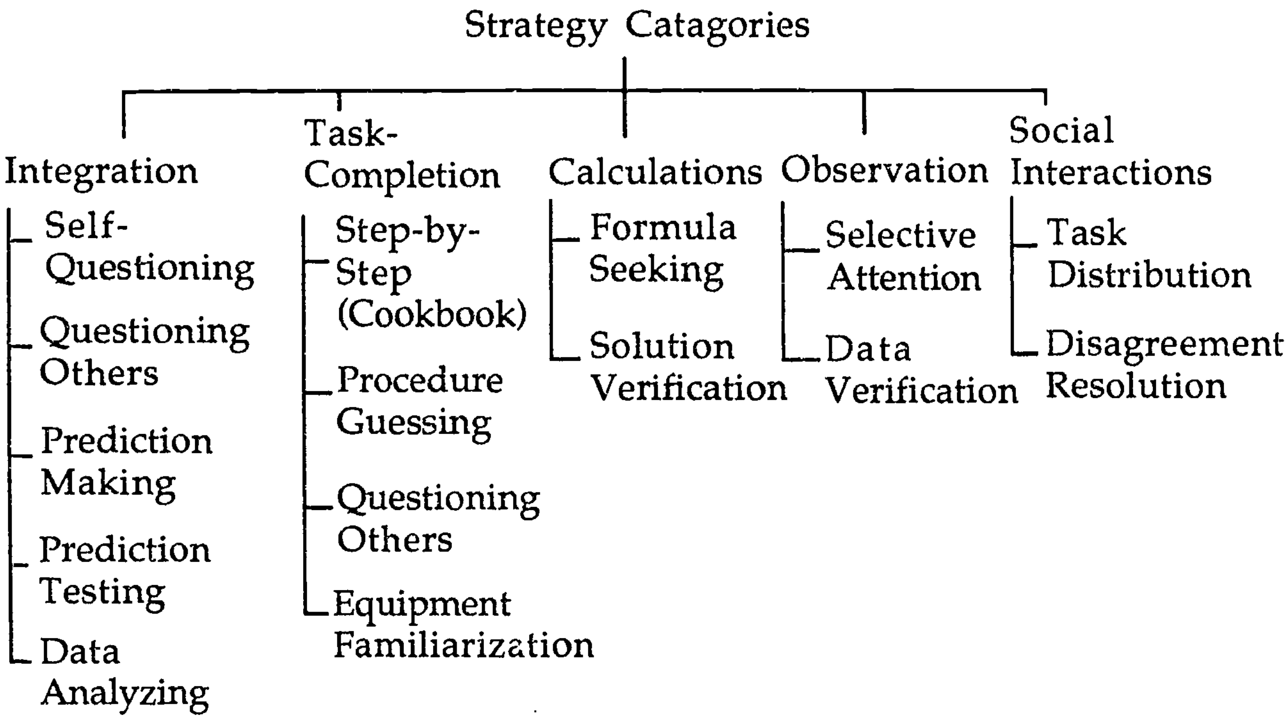
Design

The design of this study was qualitative in nature; it was a non-experimental observational design. One individual collected all field data; that individual was neither the course instructor nor the lab teaching assistant. However, the data collector did aid subjects by answering some of their questions during the laboratories. This participation was important in reducing the subjects' levels of anxiety about being audiotaped and observed. The data collected through classroom observations was used in order to determine kinds of strategies and skills subjects employed while conducting laboratory activities.

Results

The data collected through the observations revealed five different categories of strategies: integration, completion-of-task, calculation, observation, and social interactions (see Figure 1). Each of these types of strategies played a role in subjects' completion of the laboratory task and will be discussed in turn.

Figure 1



The first category, integration, was defined as the group of strategies that subjects used in attempting to relate the laboratory task to: (a) the theory presented in the lab manual, (b) the theory presented in lecture, or (c) prior knowledge. Five different strategies were identified within this category (see Figure 1). The first four strategies are self-explanatory. The fifth strategy included types of activities subjects engaged in when trying to make sense of the data collected, e.g. discussions with others and examination of textual material. The other four strategies often were exhibited when subjects were attempting to make sense of the data. However, they also appeared at other times, e.g. when subjects were examining the procedures themselves. Furthermore, the other four strategies often appeared independently of one another.

The second category, task completion, was defined as the set of strategies used by subjects to get through the various tasks required to collect data. Four primary strategies were involved (see Figure 1). (a) Step-by-step task completion was defined as the action of reading each step in the lab immediately prior to completing that portion of the task. This strategy was analogous to closely following a recipe to bake a cake, hence the reason for using the word "cookbook." (b) Procedure guessing referred to the strategy exhibited by a number of individuals who used the data table to determine how to proceed with the data collection and how to use the equipment. The subjects who employed this strategy did not examine the lab manual first. In some cases, subjects would begin with this strategy, but when a problem occurred, would incorporate use of another strategy, e.g. step-by-step. (c) Questioning others referred to the strategy of asking other people how a piece of equipment worked or where a bit of data belonged in the data table or how to proceed with the lab. In some cases, this strategy appeared with one or more of the other strategies within this category. (d) Equipment familiarization referred to the strategy of playing with the equipment (either the apparatus or computer) to see how it worked or to refine the data collection process and, presumably, data accuracy. This strategy, though independent of the others, occurred with one or more of the other strategies.

The third category, calculations, referred strictly to finding and using mathematical formulae. It included only two types of strategies: (a) hunting for formulae within the lab manual; formulae that had the appropriate variables to solve the problem and (b) verifying mathematical solutions (i.e. checking correctness of answers, comparing answer with prediction, or comparing answers with partner).

The fourth category, observation, contained two kinds of strategies (see Figure 1). The first of these was selective attention. Selective attention included two components, paying attention to the apparatus and recording observations. Throughout the lab sessions, some subjects were more observant of the lab apparatus and the actual data collection process than others. Those individuals who attended to the apparatus during the data collection process also tended to record their observations. Two types of observation recording were observed: (a) writing only observations required and (b) writing required observations and other relevant information (e.g. air currents, air pressure, error sources which could not be removed). A second strategy within this category was verification of data. Data verification was accomplished in three ways: (a) comparing the experimental data with expected data based upon prior knowledge, (b) comparing experimental data with expected data based on mathematical calculations provided in the lab manual, and (c) comparing experimental data with expected data considering the extent of possible sources of error. This differs from data analysis within the integration category in that the subjects were assessing the validity of a given bit of data rather than trying to relate the data collected with theory. In several cases, subjects calculated expected data without considering how it was relevant to the concept behind the lab. Data verification based upon those expected data were independent of data analysis. However, if data verification was conducted in conjunction with reading or other such strategies, then it was not independent of data analysis.

The last category, social interactions, contained two subcategories (see Figure 1). For the first of these types of social interactions, task distribution, several kinds of activities were observed: (a) group members acting independently, (b) a group leader assigning tasks to individuals, and (c) subjects self-assigning tasks based upon the procedures needed to be completed. The second of these social interactions, disagreement resolution, also was exhibited in a number of different kinds of actions: (a) rereading relevant portions of the lab manual, (b) questioning the instructor, (c) compromising, (d) agreeing to disagree and working separately, (e) questioning classmates, and (f) reading text or other materials, not lab manual.

Conclusions and Implications

Teaching the use of learning strategies has been shown to enhance at least some children's learning in classroom settings (Duffy & Roehler, 1989). Within the realm of science education, few strategies specific to the lab setting have been identified (Schauble, et al., 1991). Identification of such strategies is critical for eventual development of techniques to teach effective lab strategies. Through this study, five types of lab strategies were identified within an introductory science lab setting at the college level: (a) integration, (b) task-completion, (c) calculations, (d) observation, and (e) social interactions. Much work still needs to be done within this study to assess the level of effectiveness of the various strategies employed. Not all of the strategies identified were necessarily productive. Furthermore, this study is limited to introductory lab settings within which very structured labs were used. Much more research is needed to identify strategies and their effectiveness for different school settings and different laboratory types. Finally, this line of research, in conjunction with the literature in the areas of problem solving, strategy instruction, and laboratory surveys, may well provide a more well rounded picture of the potential role of laboratory use in children's attainment of scientific concepts and their understanding of the process of science.

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