Undergraduate student attitudes and perceptions toward low- and high-level inquiry exercise physiology teaching laboratory experiences

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Henige K. Undergraduate student attitudes and perceptions toward low- and high-level inquiry exercise physiology teaching laboratory experiences. Adv Physiol Educ 35: 197–205, 2011; doi:10.1152/advan.00086.2010.—The purpose of this investigation was to compare student attitudes toward two different science laboratory learning experiences, specifically, traditional, cookbook-style, low-inquiry level (LL) activities and a high-inquiry level (HL) investigative project. In addition, we sought to measure and compare students’ science-related attitudes and attitudes toward science. Students participated in 5 wk of LL activities followed by a 5-wk HL project. An open-ended survey administered at the end of the semester and analyzed by a χ²-test revealed that 1) students enjoyed the HL project more than the LL activities, 2) high-level inquiry did not have a negative effect on student motivation in the laboratory, and 3) students perceived that they learned more about physiology principles with the HL activities. Most students liked the HL project, particularly the independence, responsibility, freedom, and personal relevance. Of the students who did not like the HL project, many reported being uncomfortable with the lack of structure and guidance. Many students gained a more positive and realistic view about scientific research, often reporting an increased respect for science. Likert scale surveys administered before and after each 5-wk period showed no significant changes in student attitudes to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, or motivation toward science when the three time points were compared. The findings in this study have helped to provide suggestions for better implementation of HL projects in the future.

AN IMPORTANT ELEMENT of science teaching and learning takes place in the science teaching laboratory. Traditional science laboratory assignments are “cookbook” investigations where teachers or laboratory manuals carefully guide students through the experiments (like following the steps of a recipe) to verify something that the students already know. There is very little incentive or opportunity to think or be creative, minimizing anticipation and the stimulation of curiosity. Laboratory instruction in this traditional form is often viewed as uninteresting, boring, and tedious (17, 18, 32, 35). Humans have a natural inquisitive desire (1). A switch to learner-centered, inquiry-style laboratories, where students are in the active pursuit of answers to questions or solutions to problems, takes advantage of this natural desire and uses curiosity to drive the curriculum.

Student attitudes toward the learning experience encompass many elements, including enjoyment, motivation, and perception of learning. When educators consider their objectives in the process of designing a course, the focus is usually on the attainment of cognitive and practical skills. Improving the affective domain is often overlooked. In 1968, Mager (20) stated the following:

“The likelihood of the student putting his knowledge to use is influenced by his attitude for or against the subject; things disliked have a way of being forgotten...One objective toward which to strive is that of having the student leave your influence with as favorable an attitude toward your subject as possible. In this way you will help to maximize the possibility that he will remember what he has been taught, and will willingly learn more about what he has been taught.”

An improved attitude toward the learning experience may lead to higher achievement, since more positive attitudes toward the science learning experience have been associated with better achievement in science (18, 19).

Traditional classroom environments are teacher centered, where the teacher provides instructions and makes decisions. Students are allowed little to no input in the learning process. Inquiry learning is based on the constructivist perspective. There is no single constructivist theory; however, many of the theories recommend common classroom characteristics (34). The learning environment should be learner centered, where students are responsible for their own learning and have an active role in building their own knowledge and understanding. The learning context should be complex and challenging, requiring higher-level thinking skills such as application, analysis, synthesis, and evaluation (3). The learning tasks should have a connection to authentic problems. There should be social negotiation and shared responsibility among students.

Inquiry learning can be applied at different levels. In 1962, Schwab proposed a three-level taxonomy of openness and permissiveness for inquiry instruction (27). Schwab’s three levels were later revised into four levels by Herron (13). The Schwab-Herron system provides three areas that can be modified to vary the level of inquiry presented to students (Table 1). Level 0 essentially represents a lack of inquiry. As the level increases, students become more involved in the learning process. Level 3 represents full inquiry, where students take full responsibility for an investigation, from posing a question to answering it. In the literature, there are many investigations into the effect of increasing the level of inquiry on student attitudes toward science. However, the existing studies have used a variety of inquiry levels and research protocols, making comparisons and conclusions difficult. In most studies, the level of inquiry was either not defined or was defined loosely.

The investigatory approach to teaching in the laboratory uses Schwab-Herron level 3 inquiry. These project laboratories generally last several weeks, and the students are responsible for all aspects of the investigation. This approach closely resembles what real scientists do.
Before students can effectively participate in a full level 3 inquiry, it is generally recommended that they should first spend time learning basic laboratory techniques and procedures. In addition, students should learn at least the basic principles of the scientific process and research design. Students should also perform guided (midlevel) inquiry investigations before participating in full inquiry.

In an investigative project, small groups of students (preferably 2–5 students/group) ask a question or identify a problem that is authentic and personally relevant and interesting. The groups then gather information about the topic, write a hypothesis, design an experiment, write a research proposal, and spend several weeks collecting and analyzing data. The final product is typically a written report formatted like a journal article. In addition, the students may present their data and an interpretation of their results to the class. Evaluation of the investigative laboratory approach has been primarily based on qualitative data from case studies. The feedback from students and teachers has been generally positive (2, 6, 8, 16, 22, 29, 32).

The purpose of this project was to compare student attitudes and responses toward two different science laboratory learning experiences. Specifically, reactions to traditional, cookbook-style, low-inquiry level (LL) activities and a high-inquiry level (HL) investigative project were compared. In addition, student’s science-related attitudes and attitudes toward science were measured and compared before and after they were taught with each of the two methods.

METHODS

Population and Sample

Thirty-nine of forty undergraduate Kinesiology majors enrolled in a fourth-year advanced exercise physiology course participated in the study. Subjects included both male and female students. The advanced course is the last of four exercise physiology courses required of all Kinesiology majors and taken in succession. Each course includes a corequisite laboratory section. In the three previous laboratory sections, students were introduced progressively to statistics, graphing, internet and library research, hypothesizing, investigative research design, data collection, report writing, and oral presentation. In addition, students learned numerous laboratory skills, such as how to measure aerobic capacity, body composition, muscular power, metabolic rate, etc.

Students were blind to the details of the investigation. When students were asked to compare the two treatments, they were asked to compare the first 5-wk period with the second 5-wk period. The terms “low-level inquiry” and “high-level inquiry” were never used with the students.

Before data collection began, each subject was given an information sheet to read and keep. Both the study protocol and information sheet were previously approved by the University Park Institutional Review Board (USC UPIRB no. 04-12-393) of the University of Southern California. Each subject participated voluntarily.

Research Procedure

The 10-wk research protocol is shown in Table 2. Students worked in the same self-selected group of three to five students during the entire semester. Students were required to purchase a student laboratory manual that was written by the investigator.

Inquiry Treatments

LL The treatment conditions (Table 3) were based on the classic Schwab-Herron levels of the laboratory openness scale (Table 1). For the first 5-wk period, students participated in three level 0–1 inquiry laboratory activities (Table 2). For each laboratory activity, the student laboratory manual contained a detailed introduction, background information, step-by-step instructions, and a written assignment (laboratory report). Students were not explicitly told what to expect for the results; however, the laboratory manual contained sufficient information so that the students who read and comprehended it would know what to expect. In addition, students were given guidance by their teaching assistant (TA) to assist them in the completion of their laboratory reports. Each laboratory began with a quiz based on a reading assignment in the laboratory manual. After the quiz, the TA gave a short lecture to provide background information and instructions for completion of the laboratory activity and report.

HL During the second 5-wk period, the laboratory assignment was a level 3 investigative project. Student groups were required to develop a research question. Other than safety, the only constraint for

Table 1. Schwab-Herron levels of laboratory openness

<table>
<thead>
<tr>
<th>Level</th>
<th>Problem</th>
<th>Ways and Means</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Given</td>
<td>Given</td>
<td>Given</td>
</tr>
<tr>
<td>1</td>
<td>Given</td>
<td>Given</td>
<td>Open</td>
</tr>
<tr>
<td>2</td>
<td>Given</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>3</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
</tbody>
</table>

Table 2. Semester outline/research protocol

<table>
<thead>
<tr>
<th>Activity</th>
<th>Assessment</th>
<th>Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LL activities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 1</td>
<td>Students are taught how to calibrate and use the various pieces of equipment that will be used over the next 4 wk</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>Laboratory 1: aerobic capacity</td>
<td>Quiz on laboratory 1</td>
</tr>
<tr>
<td>Week 3</td>
<td>Laboratory 2: lactate threshold</td>
<td>Quiz on laboratory 2; laboratory 1 due</td>
</tr>
<tr>
<td>Week 4</td>
<td>Laboratory 3: glucose homeostasis during exercise</td>
<td>Quiz on laboratory 3; laboratory 2 due</td>
</tr>
<tr>
<td>Week 5</td>
<td>Laboratory 3: continued</td>
<td>Project proposal due</td>
</tr>
</tbody>
</table>

**HL Investigative Project**

| Week 6 | Investigative laboratory project | Laboratory 3 due | Second LSS |
| Week 7 | Investigative laboratory project | | |
| Week 8 | Investigative laboratory project | | |
| Week 9 | Investigative laboratory project | | |
| Week 10 | Investigative laboratory project presentation | Project report due | Third LSS; OES |

LL, low inquiry level; HL, high inquiry level; LSS, Likert-scale survey; OES, open-ended survey.
choosing their topics was the equipment and supplies available. Students were provided a long list of tests they had previously used and skills previously acquired, as a reminder of the possible methods available to them (see APPENDIX A in the Supplemental Material for the list). Students were also required to do a brief literature review, write a hypothesis, design and administer a research protocol, analyze the data, interpret the findings, and present it by way of both a journal article-style write up and a PowerPoint presentation. The TAs were careful not to give the students explicit information about the planning, implementation, or interpretation of the results of the investigation. However, students received minimal guidance, as needed, by way of small tips and prompts throughout the project. The student laboratory manual provided an outline of the elements required for a written project proposal, which was due before beginning data collection. In addition, the laboratory manual contained an outline of a typical experimental design (i.e., the generic steps, from establishing the research question to presenting the results). Finally, the laboratory manual contained an outline for the written report, which explained the required sections, purpose of each section, and guidelines for ensuring a thorough report.

TAs

The laboratories were taught by TAs, not the investigator. The TAs had been previously taught with level 3 inquiry methodology in the exercise physiology laboratory. Additionally, the investigator spent time teaching and training the TAs how to apply different levels of inquiry in the teaching laboratory. The investigator randomly attended laboratory sections throughout the semester to confirm compliance by the TAs with the guidelines for teaching the desired levels of inquiry.

Open-Ended Survey

An open-ended survey (OES) was given to the students after they completed both inquiry treatments (see APPENDIX B in the Supplemental Material for the OES). A portion of the OES questions asked the students to compare the two 5-wk treatment periods (LL vs. HL) in terms of enjoyment, motivation, and learning. Students were also asked whether the investigative project influenced their view of scientific research and postgraduate and career plans. Finally, students were asked to briefly discuss their responses and explain what they liked the most and least about the project.

Likert-Scale Student Attitude Survey

Four different dependent variables were assessed quantitatively with a Likert-scale survey (LSS) based on subscales from two different existing surveys (see APPENDIX C in the Supplemental Material for the LSS). Part I of the LSS included subscale questions from the Test of Science-Related Attitudes (TOSRA) and was used to assess 1) attitudes toward scientific inquiry, 2) adoption of scientific attitudes, and 3) enjoyment of science lessons (11). Part II of the LSS used subscale questions from the Student Attitudes Toward Science (STU-ATT) questionnaire to measure student motivation toward science (7). The investigator used the original instruction manuals for the administration and scoring of the individual components of the TOSRA and STUATT questionnaires. The LSS was administered at the beginning of the laboratory period, three times over the semester: 1) on week 1, before beginning the LL activities (first LSS); 2) on week 6, after completing the LL activities but before beginning the HL project (second LSS); and 3) on week 10, after completing the HL project (third LSS) (Table 2).

Data Analysis

\( \chi^2 \)-analyses were used to determine whether students’ attitudes toward the two learning experiences differed. One-way repeated-measure ANOVA was used to determine whether students’ science-related attitudes and attitudes toward science changed. Statistical significance was set at \( P < 0.05 \).

RESULTS

OES

Students were asked which 5-wk period they enjoyed more, which they felt more motivated toward, and which resulted in more learning. Students had the option of replying the first half (LL activities), the second half (HL project), or that both were the same. The results are shown in Table 4. Students were also asked whether they felt that the project had an influence on their view of scientific research or their postgraduate and career plans. Finally, students were asked to briefly explain why, and their comments

Table 4. OES results

<table>
<thead>
<tr>
<th></th>
<th>First Half (LL Activities), %</th>
<th>Second Half (HL Project), %</th>
<th>Same (Neutral), %</th>
<th>Yes, %</th>
<th>No, %</th>
<th>( n )</th>
<th>( \chi^2 )-Analysis</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which did you enjoy more?</td>
<td>17.9</td>
<td>46.2</td>
<td>35.9</td>
<td></td>
<td></td>
<td>39</td>
<td>12.32</td>
<td>0.00</td>
</tr>
<tr>
<td>During which half did you feel more motivated?</td>
<td>33.3</td>
<td>30.8</td>
<td>35.9</td>
<td></td>
<td></td>
<td>39</td>
<td>0.39</td>
<td>0.82</td>
</tr>
<tr>
<td>During which half do you think you learned more?</td>
<td>59.0</td>
<td>17.9</td>
<td>23.1</td>
<td></td>
<td></td>
<td>39</td>
<td>30.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Did the project influence the way you view scientific research?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Did the project influence your postgraduate plans?</td>
<td>11.4</td>
<td>88.6</td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>59.60</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\( n \), Number of students.
are shown in Table 6. Students were also asked what they liked the most and least about the second half, and the comments are shown in Table 7. In both Tables 6 and 7, any comment given by more than one student was included.

**Enjoyment.** Students were asked “which half did you enjoy more?,” and differences were found in their responses (Table 4). Post hoc analysis revealed that significantly more students enjoyed the second 5-wk period (HL project) more (Table 5).

**Motivation.** When students were asked “during which half did you feel more motivated to go to the laboratory and to be in the laboratory?,” student responses were evenly distributed among the second half (HL project), the first half (LL activities), and both the same (Table 4).

**Perception of learning.** Students were asked “during which half do you think you learned more, specifically, which half helped you to understand physiological principles better?” Differences were found in the responses (Table 4), and post hoc analysis indicated that significantly more students perceived that they learned more during the first 5-wk period (LL activities; Table 5).

**View of scientific research.** When asked whether the project had “an influence on the way you view scientific research?,” most students reported that their view had not changed (Table 4). Postgraduate and career plans. When students were asked “Did this project have any influence on your postgraduate or career plans?,” most students said that it did not (Table 4).

**LSS**
Means and SDs found for each attitude measure, at each time point, are shown in Table 8. Values represent the means of the sums of each set of subscale scores. Higher sums represent the measurement of a more positive attitude. Four one-way repeated-measure ANOVAs were conducted with the factor being week and the dependent variables being the four different attitude measures. The results of the ANOVAs indicated no significant difference in any of the variables when the time points were compared (Table 9).

**DISCUSSION**

**Enjoyment**
Students were asked whether they enjoyed the first or second half of the semester more (LL activities vs. the HL project). More students enjoyed the HL project better, and this finding is

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**Table 5. OES results: post hoc analysis**

<table>
<thead>
<tr>
<th></th>
<th>First Half (LL Activities), %</th>
<th>Second Half (HL Project), %</th>
<th>n</th>
<th>χ²-Analysis</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which did you enjoy more?</td>
<td>28.0</td>
<td>72.0</td>
<td>25</td>
<td>19.36</td>
<td>0.00</td>
</tr>
<tr>
<td>During which half do you think you learned more?</td>
<td>77.0</td>
<td>23.0</td>
<td>30</td>
<td>29.16</td>
<td>0.00</td>
</tr>
</tbody>
</table>

n, Number of students. *A total of 39 students completed the survey, but not all of the students responded to all of the questions.

**Table 7. OES student comments about the HL project**

<table>
<thead>
<tr>
<th>Comments</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liked the most</strong></td>
<td></td>
</tr>
<tr>
<td>What did you like the most about the second half?</td>
<td>39</td>
</tr>
<tr>
<td>Independence/responsibility/freedom</td>
<td>13</td>
</tr>
<tr>
<td>More personally relevant</td>
<td>11</td>
</tr>
<tr>
<td>Got to do our own experiment</td>
<td>7</td>
</tr>
<tr>
<td>More applied</td>
<td>4</td>
</tr>
<tr>
<td>Anticipation of results</td>
<td>3</td>
</tr>
<tr>
<td>Greater sense of accomplishment/ownership</td>
<td>2</td>
</tr>
<tr>
<td><strong>Liked the least</strong></td>
<td></td>
</tr>
<tr>
<td>What did you like the least about the second half?</td>
<td>37</td>
</tr>
<tr>
<td>Nothing</td>
<td>12</td>
</tr>
<tr>
<td>Lack of structure</td>
<td>7</td>
</tr>
<tr>
<td>Working in a group</td>
<td>7</td>
</tr>
<tr>
<td>It was a lot of work</td>
<td>6</td>
</tr>
<tr>
<td>Don’t like the research process</td>
<td>3</td>
</tr>
</tbody>
</table>

**View of scientific research**

For those that reported that the project influenced their view of scientific research, briefly explain. 14*

For those that reported a more positive view of scientific research, briefly explain. 14*

Increased respect for scientific research 7

I understand scientific research better now 2

n, Number of students. *A total of 39 students completed the survey, but not all of the students responded to all of the questions.
and HL teaching laboratories were compared, and quantitative
student attendance, participation, and interaction during LL
interpreted as increases in motivation. In another study (31),
higher levels of inquiry in the laboratory, which could be
received increases in student enthusiasm, energy, and effort with
Many studies (16, 18, 25, 31) have reported instructor-per-
the term “motivation” was not defined for the students
it can be defined and measured many different ways. In this
investigation. Results showed no consensus. The problem with
making conclusions and comparisons about motivation is that
consistent with similar research conducted on high school and
undergraduate students (7, 14, 16, 18, 31).
The students who enjoyed the HL project more were asked
to explain why, and multiple responses were given. Some
students simply replied that they liked being able to do their
own experiments. It is unclear what aspect of “doing their
own” experiment made it enjoyable for them. It could be that
they liked the independence, responsibility, or ability to make
the project personally relevant. Some students specifically
stated that they enjoyed the independence, responsibility, and
freedom they were afforded during the project, and this finding
has been previously reported (16, 22, 29, 33). Some said that
the project was more personally relevant, since they were able
to choose their own topic. Other students reported that the
project was more “fun,” a word that has been used by students
to describe HL projects in other, similar investigations (22, 24).
Other students liked the HL project because it allowed a more
focused and indepth approach or because it was a more applied
use of the course content. For students who enjoyed the LL
activities more, the reasons given were that they liked the
structure and felt they learned more.

Motivation

Students were asked specifically about their motivation to go
to the laboratories and be in the laboratories during this
investigation. Results showed no consensus. The problem with
making conclusions and comparisons about motivation is that
it can be defined and measured many different ways. In this
study, the term “motivation” was not defined for the students
and, therefore, this left room for individual interpretations.
Many studies (16, 18, 25, 31) have reported instructor-per-
ceived increases in student enthusiasm, energy, and effort with
higher levels of inquiry in the laboratory, which could be
interpreted as increases in motivation. In another study (31),
student attendance, participation, and interaction during LL
and HL teaching laboratories were compared, and quantitative
analysis revealed significantly greater values during HL labo-
ratories. Again, these findings could be interpreted to represent
an increase in student motivation. For the present investigation,
we cannot conclude that the students in this investigation were
more motivated during the HL project. However, it appears
that, at the least, the higher-level inquiry did not have a
negative effect on motivation.

Students who reported greater motivation during the HL
project attributed it to some of the same reasons given for
enjoying it more, including personal relevance. Again, some
students simply replied that they felt more motivated when
they were able to do their own experiments. Others claimed
that the HL project was more motivating because it was more
fun. Based on the work of educational psychologists, students
who are motivated by these characteristics are thought to be
intrinsically motivated. Intrinsic motivation is driven by internal
and personal needs such as curiosity, interest, and enjoyment
(34). Curiosity is an emotion related to natural inquisitive
behaviors, such as investigation. Intrinsic motivation has also
been described as a tendency to seek and conquer challenges
(34). Because inquiry learning is not what the students are
accustomed to, and because they receive less structure and
guidance, it tends to be more difficult and require more work
on their part. In general, inquiry also requires higher-level
thinking skills, adding to the challenge.
The group who reported that they were more motivated
during LL activities credited their motivation primarily to the
structure and clear objectives. Other students more motivated
during LL activities ascribed it to the mandatory nature of
regular laboratory reports and quizzes, part of the structure and
frequent external accountability typical of LL activities. Ex-
trinsically motivated students are motivated best when they are
required to do something; the reason for doing the activity has
little, if anything, to do with the activity itself. These students
work for some type of external reward (i.e., high grades, to
please the teacher, etc.) or to avoid punishment (i.e., low
grades, disappointing the teacher, etc.). These students do not
value the process as much as the grade at the end. Higher-level
inquiry is all about the process.
The results of this investigation raise the question of whether
there is a connection between a student’s motivation type
(intrinsic vs. extrinsic) and their preference for inquiry level
(high vs. low) in the laboratory. Future research should inves-
tigate this question.

Perception of Learning

The majority of the students said that they learned more with
LL activities. Reasons given by students were that more topics
and principles were covered, and the laboratory manual and
TAs provided more information during LL activities. A small
percentage of students felt that they learned more during the
HL project, and they attributed it to being on their own, forced
to think on their own and in more depth. In a previous

<table>
<thead>
<tr>
<th>Table 8. LSS results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Attitude to scientific inquiry (10 questions worth 1–5 points each)</td>
</tr>
<tr>
<td>First LSS 32.93 ± 6.77</td>
</tr>
<tr>
<td>Second LSS 34.35 ± 6.87</td>
</tr>
<tr>
<td>Third LSS 33.30 ± 6.73</td>
</tr>
<tr>
<td>Adoption of scientific attitudes (10 questions worth 1–5 points each)</td>
</tr>
<tr>
<td>First LSS 38.83 ± 4.13</td>
</tr>
<tr>
<td>Second LSS 38.80 ± 4.17</td>
</tr>
<tr>
<td>Third LSS 38.20 ± 5.21</td>
</tr>
<tr>
<td>Enjoyment of science lessons (10 questions worth 1–5 points each)</td>
</tr>
<tr>
<td>First LSS 37.75 ± 4.83</td>
</tr>
<tr>
<td>Second LSS 38.53 ± 6.16</td>
</tr>
<tr>
<td>Third LSS 37.83 ± 6.01</td>
</tr>
<tr>
<td>Student motivation toward science (8 questions worth 1–5 points each)</td>
</tr>
<tr>
<td>First LSS 21.73 ± 5.39</td>
</tr>
<tr>
<td>Second LSS 22.78 ± 5.12</td>
</tr>
<tr>
<td>Third LSS 22.93 ± 5.02</td>
</tr>
</tbody>
</table>

These values are means ± SE; n = 39 students total.

Table 9. One-way repeated-measures ANOVA results

<table>
<thead>
<tr>
<th></th>
<th>Wilkes’ Λ</th>
<th>F_{2,38}</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude toward scientific inquiry</td>
<td>0.976</td>
<td>0.465</td>
<td>0.631</td>
</tr>
<tr>
<td>Adoption of scientific attitudes</td>
<td>0.986</td>
<td>0.274</td>
<td>0.762</td>
</tr>
<tr>
<td>Enjoyment of science lessons</td>
<td>0.985</td>
<td>0.280</td>
<td>0.757</td>
</tr>
<tr>
<td>Student motivation toward science</td>
<td>0.970</td>
<td>0.585</td>
<td>0.562</td>
</tr>
</tbody>
</table>

n = 39 students total.
What Students Liked the Most About the Project

Regardless of which level of inquiry they enjoyed more or felt more motivated about, students were asked what they liked the most about the HL project. Again, common themes from other questions were reiterated. Students favored the independence and responsibility of the HL project. Students liked having the freedom, including the ability to choose a topic of personal interest. New themes arose as students mentioned that they liked being able to apply their knowledge and felt a greater sense of ownership and accomplishment. Students also mentioned the excitement and suspense of getting their results (something that is usually absent in LL activities because the students already know what to expect). This curiosity and excitement has been previously reported with similar projects (22, 25, 28, 33).

View of Scientific Research

About one-third of the students reported that their “view of scientific research” had changed, and all of these students indicated that their current attitude is now more positive. These students explained that they now have a new level of respect and appreciation for scientists, what they do, and the difficulties involved in research. Other investigators (9, 16) have also reported the student perception that HL investigations are harder and require more work. Moreover, as mentioned above, students are not generally accustomed to HL, and this often leads to an uncomfortable struggle and sense of frustration.

Student Anxiety

It has been previously reported that students tend to feel an increased level of anxiety and frustration while doing HL activities (4, 28, 29, 33). Although anxiety was not addressed directly in this investigation, there was evidence of increased anxiety during the HL project for some students. As mentioned above, some students expressed a sense of frustration with group members, and some students reported being uncomfortable with the lack of structure and support. One student said that they did not like coming to the laboratory during the
second 5-wk period (HL project) because they “always knew there was going to be a problem with our machine and [that] it would take forever.” Students, in general, do not have a realistic perception of how scientific investigations run. In most teaching environments, teachers and TAs perform activities that have low rates of complication and high rates of success, in essence shielding the students from the realities of scientific investigations. The students in this study may not have been mentally prepared for the problems that often arise during a research investigation.

**Postgraduate and Career Plans**

As would be expected in fourth-year undergraduate students, the HL project did not cause a change in most students’ postgraduate or career plans. However, some students indicated that they now realize that scientific investigations can be complicated and difficult. Two students specifically stated that they now know they do not want to do research as a career. Similar comments have been previously reported (16, 29). A few other students expressed a stronger drive to study physiology, also consistent with previous findings (8). Both positive and negative influences on a students’ decision to go to graduate school are valuable and useful early in a student’s educational career.

**LSS**

Based on the LSS data, we must conclude that there was no change in the student attitudes measured in response to participation in either LL activities or the HL project. However, it is important to point out some possible weaknesses of this data. The survey used in this study was based on subscales from two different existing surveys. Although both of these existing surveys have previously been shown to be reliable, the reliability testing was done with secondary students (7, 11, 15, 30). The subjects in this investigation were undergraduate students. Cronbach’s α-test is a test of internal consistency, indicating how closely questions within a subscale are related. A Cronbach’s α-value of 0.70 or higher is generally desired. When Cronbach’s α-value was measured on the first LSS, three of the four subscales were found to have low values (Table 10). In addition, content validity (the extent to which the questionnaire accurately measures the desired variable) has not been determined for three of the four subscales used in this investigation. In hindsight, more thought should have been put into the design of the LSS.

Because the questions on the LSS were originally designed for secondary-level students, they were worded in very simple terms. The unsophisticated nature of the questions (e.g., “science lessons are fun”) may have set the tone for student responses to the OES, leading to short, simple answers given little thought. If the present investigation was repeated, the LSS would be significantly revised to better match the population and objectives of the study.

**Limitations With the Population**

It is important to reiterate that these students were fourth-year Kinesiology majors who had already completed numerous science laboratory courses. It may have been unrealistic to expect changes in general attitudes toward science since these students were already well committed to the field and had extensive experience with science. Investigators (5, 18) have found that students taught with inquiry methods acquire significantly enhanced science attitudes, but these studies have been done with nonmajors and/or in introductory courses. In addition, it is likely that prior experiences affected student attitudes, reactions, and responses to the teaching methods in the present investigation. For a more controlled analysis of LL versus HL activities, it would be best to use a less experienced population.

**Other Considerations**

It is commonly thought that not all students are ready for full level 3 inquiry. The Schwab-Herron taxonomy is often used as a guide for introducing inquiry progressively and to assist in the development of the knowledge and skills required by inquiry. The students in the present investigation had been previously, intentionally, and progressively introduced to inquiry levels 0—2 in prior laboratory courses within the same department. For the present investigation, LL activities occurred before the HL project. This sequence was used because the project was considered a culminating project for students in their final semester before graduation. The nonrandom structure of this research design may have had an unintended affect on the results. Based on the experience of the subjects, there was no reason they could not have done the HL project first. It would be interesting to investigate differences in student responses when the order of treatment is modified (LL activities first vs. the HL project first). In addition, it would be interesting to investigate the effects of exposing students to full level 3 inquiry without the progressive introduction followed by LL activities. Prior exposure to HL activities may result in students becoming more aware of the concepts and skills required for HL activities and therefore may strengthen their appreciation and motivation to learn during LL activities.

**Conclusions**

The OES provided insight about student attitudes and responses specific to the teaching methods used in the laboratory course. The findings from this survey suggest that, in general, 1) students enjoy the HL projects more than LL activities, 2) high-level inquiry does not have a negative effect on student motivation in the laboratory, and 3) students perceived that they learned more about physiology principles with LL activities. Most students liked the HL project, particularly the independence, responsibility, freedom, and personal relevance. Of the students who did not like the HL project, many reported being uncomfortable with the lack of structure and guidance. Many students gained a more positive and realistic view about scientific research, often reporting increased respect for science. The HL investigative project did not result in measurable quantitative changes in general student attitudes toward

**Table 10. Reliability analysis of the first LSS**

<table>
<thead>
<tr>
<th></th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude toward scientific inquiry</td>
<td>0.591</td>
</tr>
<tr>
<td>Adoption of scientific attitudes</td>
<td>0.365</td>
</tr>
<tr>
<td>Enjoyment of science lessons</td>
<td>0.716</td>
</tr>
<tr>
<td>Student motivation toward science</td>
<td>0.325</td>
</tr>
</tbody>
</table>
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scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, or motivation toward science. However, it may not have been realistic to expect such changes with an advanced and experienced group of science majors. The findings in this study have helped to provide suggestions for better implementation of HL projects in the future.

Practical Implications

The following thoughts and recommendations are based partly on the data collected in the present investigation and partly on the author’s experience and personal opinion. The transition from LL to HL investigations is sometimes difficult for students, because it is generally not the way they are accustomed to learning. Students who were least comfortable with the HL project said that they prefer more structure and guidance. As indicated above, this preference could be linked to motivation type, specifically, students more extrinsically motivated may be more comfortable with LL activities. Because there are likely extrinsically motivated students in every class, instructors implementing HL projects should find ways to provide more extrinsic motivation without compromising the defining characteristics of HL activities. For example, students can be given several short deadlines rather than a 5-wk period with one large write-up due at the end. As a result of this investigation, we have since broken down the project and required five different written deadlines: 1) a list of references, 2) a research proposal, 3) an introduction and methods, 4) a first draft, and 5) a final draft.

Frustration with group members was a common complaint among students. The instructor can help to alleviate such problems by watching for group tension and intervening as needed. Two new methods that have been implemented since this investigation are group contracts and group member grading. It seems that these methods have helped increase individual accountability and the perception of fairness, subsequently reducing problems within groups.

Some students experienced frustration with technical and procedural problems that arose during their investigations. It helps to ease some of this anxiety if the instructor makes it explicitly known that problems do occur and that they should be anticipated. For example, students need to know that sometimes data has to be recollected, so they need to plan their time accordingly. Some students come to realize that their research protocol has weaknesses after they have invested a significant amount of time collecting data. Because in the teaching environment there is usually a limited amount of time, anxiety can be reduced for these students by emphasizing the learning process over good data. Within some limit, groups should not be penalized for honest weaknesses and limitations that they recognize and address in their final report; the important thing is that they learn from their mistakes. In an ideal and successful inquiry environment, students are not afraid to take risks and make mistakes, as long as they can learn from them.

Many students said they liked LL activities better because they covered more topics, and, as a result, they learned more. HL projects involve less assigned reading, lecturing, and new terminology, but cultivate other skills and attitudes that may not be recognized by many students. Instructors should make the objectives and potential benefits of the project clear, outlining the variety of knowledge, skills, and abilities they will be learning and practicing.

Many of the student projects were very similar to laboratories that the students had previously completed. To ensure a wider variety of projects, the instructor should provide careful guidance to the student groups as they develop their research questions. Topics should not be chosen for them, but students should be encouraged to expand their ideas and incorporate new concepts. Since this investigation, a notebook of sample projects and research articles has been assembled to provide examples of the types of projects that are possible and expected.

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DISCLOSURES

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