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Dohn NB, Fago A, Overgaard J, Madsen PT, Malte H. Students' motivation toward laboratory work in physiology teaching. *Adv Physiol Educ* 40: 313–318, 2016; doi:10.1152/advan.00029.2016.—The laboratory has been given a central role in physiology education, and teachers report that it is motivating for students to undertake experimental work on live animals or measuring physiological responses on the students themselves. Since motivation is a critical variable for academic learning and achievement, then we must concern ourselves with questions that examine how students engage in laboratory work and persist at such activities. The purpose of the present study was to investigate how laboratory work influences student motivation in physiology. We administered the Lab Motivation Scale to assess our students' levels of interest, willingness to engage (effort), and confidence in understanding (self-efficacy). We also asked students about the role of laboratory work for their own learning and their experience in the physiology laboratory. Our results documented high levels of interest, effort, and self-efficacy among the students. Correlation analyses were performed on the three motivation scales and exam results, yet a significant correlation was only found between self-efficacy in laboratory work and academic performance at the final exam. However, almost all students reported that laboratory work was very important for learning difficult concepts and physiological processes (e.g., action potential), as the hands-on experiences gave a more concrete idea of the learning content and made the content easier to remember. These results have implications for classroom practice as biology students find laboratory exercises highly motivating, despite their different personal interests and subject preferences. This highlights the importance of not replacing laboratory work by other nonpractical approaches, for example, video demonstrations or computer simulations.

motivation; interest; self-efficacy; self-determination theory; laboratory work

THE LABORATORY has been given a central and distinctive role in tertiary science education, and educators have suggested that laboratory work is an essential component of science teaching and learning, both in terms of developing students' procedural knowledge and skills in science (18, 27) and of developing students' scientific literacy (18, 39, 41). Although laboratory work is time consuming and expensive, physiology teachers report that it is motivating for students to undertake experimental work on live animals or measuring physiological responses on the students themselves (16, 30). However, very little empirical evidence exists to qualify or quantify how students' motivations toward laboratory work affect their understanding of physiology. Indeed, most previous studies have evaluated the motivation construct in vague terms, e.g., by surveying emotional aspects (enjoying physiology, having fun with physiology, etc.) without references to contemporary motivation theory (30). To avoid lack of precision in conception, it is therefore necessary both to clarify what motivation means in a psychological sense and also to consider how such impact of motivation can be effectively studied.

Motivation refers to the process whereby goal-directed activities are instigated and sustained, and it is critically important for sustaining learning activities (29). It is likely that there are multiple motivational pathways for the direction of behavior as students come to a laboratory exercise with different interests, value, and self-efficacy beliefs. Some students may be motivated and sustained through their self-efficacy beliefs (5), whereas others are motivated to try hard, persist, and achieve because of their goals, their personal interests, their value beliefs, or contextual factors that motivate, support, and direct their behavior (29, 35). According to Pintrich (29), it is productive to understand these multiple pathways through research that examines how different personal and contextual factors interact to generate different patterns of motivated behavior. Thus, the present study combines two theoretical approaches on motivation: *1*) reasons why individuals engage in different activities (these theories include constructs such as interest as well as intrinsic and extrinsic motivation) (10, 35) and *2*) beliefs about competence and expectancy for success (5). Theories on interest and intrinsic motivation have to do with incentives or reasons for doing an activity. Even if students are certain they can do a task, they may have no compelling reason to do it. Interest and intrinsic motivation are related to the question "Why should I do this task?." Expectancies for success refer to beliefs about how one will do on different tasks or activities. These beliefs are directly related to the question "Can I do this task?." To sum up, we can say that to motivate students, their interest must be triggered and sustained; the instruction must be perceived to be relevant to personal value (or instrumental to accomplishing desired extrinsic goals like passing the course); and the students must have the personal conviction that they will be able to succeed. This is very much in line with Keller's approach for designing motivating instruction (19–21). According to Keller's ARCS model of motivational design, there are four general requirements to be met in order for people to be motivated to learn. The first requirement is to obtain and sustain students' attention. The second requirement is the need for personal relevance, where the faculty member has to fulfill the students' needs and goals. The third requirement is confidence or expectancy for success. Here, a faculty member can help students to believe that they will succeed by designing the laboratory exercises and learning environment to establish an appropriate level of confidence in regard to the students' expectancies for success. The fourth requirement is satisfaction with the learning outcome. Although design principles are highly relevant for instruction, they will always need to be adapted to the affordances and constraints operating in the learning context.

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Below, we discuss modern theories of interest, intrinsic motivation, and self-efficacy more in detail.

Interest is a content-specific concept, i.e., it is always related to specific topics, tasks, or activities. Interest is characterized by focused attention and engagement, and the close connection between interest and learning is by many seen as self-evident; the more interest a student has in a particular topic, the more willing he or she is to learn about that topic (14, 33, 36, 37). Interest is conceptualized as a motivation variable that has both affective and cognitive components: it includes feelings and valuing of disciplinary content (e.g., physiology) as well as the perception of having and being able to develop knowledge about that content.

The emergence of interest can be examined on different levels of analysis. At the first level, interest refers to the psychological state of engagement with content. This is the case when we observe students in the laboratory and characterize their motivational state as "being interested.: Such an interest that is primarily caused by external factors is called a situational interest (23). Triggered situational interest involves the immediate affective experiences that individuals associate with the environment, whereas maintained situational interest is a more committed, deeper form of situational interest, in which individuals forge a meaningful connection with the content of the material and realize its deeper significance (22). At the second level, interest refers to the dispositional motivational structure of an individual. Here, interest is interpreted as a relatively stable tendency to occupy oneself with an object of interest (15, 32). For example, undergraduate biology students typically have a long-term individual interest in biology. In this study, we focused on maintained situational interest.

Effort and importance are separate variables in extrinsic motivation and self-determination theory (35) and refers to the willingness of students to engage in relation to how important they perceive the content and activities for their learning goals (40). Although interest and intrinsic motivation can certainly motivate students to learn, it also matters whether students consider the task important. In recent achievement motivation research, this has been operationalized most explicitly in the expectancy value theory, with task value beliefs defined in terms of four components: intrinsic interest, utility, importance, and cost (29, 43).

Students' self-efficacy beliefs determine their level of motivation, as reflected in how much effort they will invest in a task and how long they will persist in the face of obstacles. The stronger the belief in their capabilities, the greater and more persistent are their efforts. Self-efficacy is defined as people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances (5). Self-efficacy refers to a goal-directed motivation, sustained by outcome expectations concerning the anticipated consequences. From a motivational perspective, outcome expectations are important because students think about potential outcomes of various actions and act in ways they believe will allow them to attain the outcomes they value.

The purpose of the present study was to investigate how laboratory work influences student motivation in physiology. Specifically, we were interested in how much students were motivated by laboratory work in terms of experienced interest as well as their willingness to engage (effort) and their confidence in understanding (self-efficacy) and to what degree students' motivation could predict their performance in the final exam (38). Additionally, we wanted to explore how students viewed the role of laboratory work for their own learning.

METHODS

Description of the course. The Zoophysiology course is a second-year course in biology held at the Department of Biosciences, Aarhus University (Aarhaus, Denmark). A total of 135 undergraduate biology students were enrolled in the course. The course involves lectures, theoretical exercises, and laboratory exercises based on traditional curriculum and instructional methods.

The course included four comprehensive laboratory practicals, involving *1*) measurements of gas exchange and oxygen transport during rest and exercise in humans (treadmill and cycle ergometer), *2*) physiology of muscle contraction studied in cardiac muscle of fish, *3*) nerve function and action potentials studied in neurons from crab legs, and *4*) effects of temperature and activity for metabolic rate in endotherms and ectotherms. These laboratory practicals involved noninvasive use of living specimens of guinea pigs (*Cavia porcellus*) and cane toads (*Bufo marinus*) in addition to excised legs from crabs (*Carcinus maenas*) and excised hearts from rainbow trout (*Oncorhynchus mykiss*). The human exercises were conducted on the students themselves.

Assessment of motivation. Students responded to a self-report questionnaire (termed the Lab Motivation Scale) that included 21 closed statement items on interest, effort/importance, and self-efficacy (see Table 1). The items were scored on a 7-point Likert scale ranging from 7 (strongly agree) to 1 (strongly disagree). Items were adapted from various validated instruments used to assess interest, effort/importance, and self-efficacy (3, 4, 8, 24, 34). In addition, there were three open questions concerning *1*) the importance of physiology laboratories as well as their *2*) best and *3*) worst experiences in a physiology laboratory. The aim of the first open question was to get insights into students' beliefs about the role of the laboratory for their own learning. This question is conceptually aligned with the motivational subscale effort/importance, cf. self-determination theory (34, 35). The two open questions concerning best and worst experiences in the laboratory was included to reveal something of the specific reasons that cannot be grasped from the analysis of 21 closed items.

The Lab Motivation Scale was administered for 20 min within the 2-h colloquium on the week after the last laboratory work. Students noted their student ID number at the questionnaire. A total of 132 responses were completed and returned (from 55 male students and 77 female students), corresponding to a response rate of 98%.

Students' academic performance was measured by collecting data on students' exam performance by the end of the course. The evaluation of the entire physiology course consisted of a 4-h written open-ended exam. The exam tasks required information from textbooks, laboratory manuals, and laboratory reports. The exam scores were converted to a numeric score before data analysis.

Ethical considerations. We ensured full anonymity of the students, and they all voluntarily consented to our investigation after having been informed of its purpose. We have abided by all requirements in the Danish Act on Processing Personal Data given by the Danish Protection Agency (www.datatilsynet.dk).

Analysis of the closed statements. To score the Lab Motivation Scale, we reversed the scores for the items that are stated in a negative manner (*items 3*, *9*, and *11*). Then, a factor analysis and Rasch models were used to assess the dimensionality of the questionnaire. When dimensionality was validated, we calculated subscale scores by averaging across all of the items on that subscale.

The closed statement items were factor analyzed using principal factor analysis with varimax rotation (12). The general criteria for inclusion of items on subscales were a factor loading of at least 0.5 on the appropriate subscale and no cross-loadings above 0.4. The anal-

Table 1. *The scales of the 21-item Lab Motivation Scale*

Subscale	Scale Items	Factor Loading	Mean	SD	Cronbach's α
Interest	I really enjoyed the practical work very much	>0.75	6.23	0.82	0.87
	The practical work was fun to do				
	I thought the activities were boring (reversed)				
	The practical work was interesting				
	The practical work was exciting				
Effort	I think I was pretty good at the practical work	>0.54	5.69	1.08	0.88
	I think I did pretty well at the practical work				
	I am satisfied with my performance at the practical work				
	The practical work was an activity that I couldn't do very well (reversed)				
	I was very engaged in the practical work				
	I didn't try very hard to do well at the practical work (reversed)				
	It was important to me to do well at the practical work				
	I put a lot of effort into the practical work				
Self-efficacy	After working at the laboratory work, I felt pretty competent	>0.85	5.54	1.14	0.84
	I feel sure that I have learned from the practicals				
	I feel confident to tutor another student on the practicals				
	I feel confident to explain the procedures of a practical				
	I feel confident to conduct the practical from a manual				
	I feel confident to write up the results to a laboratory report				
	I feel confident to write the conclusion to a laboratory report				
	I feel confident to pass the exam				

$n = 132$. To score the Lab Motivation Scale, we reversed the scores for the items that are stated in a negative manner (*items 3*, *9*, and *11*).

ysis revealed three distinct motivational factors: interest, effort, and self-efficacy. These factors were subsequently treated as scales and subjected to the analyses of reliability by Cronbach's α, which is a reliability coefficient based on the average covariance among items in a scale (9). Cronbach's α expresses how well a set of items measures a single one-dimensional latent construct. The reliability coefficient was 0.92 for all closed items in total and between 0.84 and 0.88 for each scale (Table 1). Factor analysis and Cronbach's α were determined using the IBM SPSS (version 22) software packet.

The purpose of the Rasch analysis was to determine the extent to which the closed items conformed with a single construct. The analysis was conducted with the RUMM2030 software application. Mathematically, in Rasch measurement, when all items fit the model, there is a predominant single trait underlying all the items (25, 31, 42). The item-trait test of fit (a χ^2) examines the consistency of the item parameters across the student measures for each item, and data are combined across all items to give an overall test of fit. This shows the collective agreement for all item locations across students of differing motivation measures along the scale. The item-student test of fit examines both the response patterns for students across items and for items across students (42). The 21 items have a good fit to the measurement model, indicating a strong agreement between all 132 students to the "difficulties" of the items on the scale (see Table 2). A good model data fit and unidimensionality in subject responses provides evidence for the construct validity of the subjects' measures (25). The Rash analysis confirmed that no sex bias was present.

Table 2. *Reliabilities and fit statistics to the Rasch measurement model for the 21-item Lab Motivation scale*

Nonfitting items	none
Items with disordered thresholds	none
Items with residuals $-2 > x > +2$	21
Cronbach's α	0.915
Index of student separability*	0.908
Item mean (SD)	0.000 (1.217)
Student mean (SD)	1.832 (0.842)
Item-trait interaction† ($P < 0.00001$)	349.521
Power of test of fit	excellent

$n = 132$. *The index of student separation is the proportion of observed variance that is considered true (91%) and is high. †The item-trait interaction test is a χ^2. The results indicate some interaction between the item's difficulty and level of personal parameters (satisfaction).

Analysis of the open-ended items. Student responses to the open-ended items were analyzed by inductive coding. An inductive approach means that the themes identified are strongly linked to the data themselves (28). Student responses were first informally reviewed to get a general sense of any themes they might contain. Student answers were then structured by open coding, i.e., the written responses were coded for emerging themes (6). Through the analysis, several student responses were excluded for further examination, as they were more evaluative and thus not relevant for this study. These include positive and negative comments on specific teachers (e.g., "Our professor NN is fun" or "In the blood lab, the instructor NN was not so enthusiastic, skipped over explanations"), specific details (e.g., "The crab leg was fun" or "The other students had used all hematocrit capillary tubes"), and comments like "I don't think there has been any negative experiences." Thus, the number of student responses for the themes in positive/negative experiences do not sum up to the total number of students. The themes are shown in Table 3.

RESULTS

Correlation analyses were performed on the three motivation scales and exam results. A significant correlation was found between self-efficacy in laboratory work and academic performance at the final exam ($P = 0.014$). No significant correlation was found between interest and academic performance or effort/importance and academic performance.

Students found the laboratory work highly interesting (mean: 6.23, SD: 0.82). Mode values, i.e., the values that appeared most often in the data set for the five interest items, were either 6 or 7, corresponding to "agree" and "strongly agree."

Students valued their effort and the importance of laboratory work as well as their self-efficacy relatively high (mean: 5.69, SD: 1.08, and mean: 5.54, SD: 1.14, respectively). Mode values for all effort/importance items were 6, corresponding to "agree," and self-efficacy items ranged from 5 to 7, corresponding to "somewhat agree" and "strongly agree" (see Table 1).

Table 3. *Themes of the open-ended items, ranked by frequency*

Theme	n
Importance of the physiology laboratory	
Makes it easier to understand theory	110
Gives insights into research methods	12
Makes it easier to remember physiology	9
Motivating	6
Best experience in a laboratory	
Allowed us to experience/demonstrate/understand theory in practice	41
Allowed us to discuss with the instructors/professors	21
We had good laboratory results	13
Report writing increased understanding	5
We made experiments on our own body	3
Worst experience in a laboratory	
Missing data due to apparatus failure	27
Group organization (too many students, distribution of duties, or time pressure)	17
Missing data due to student failure	6
Monotonous workflow (repetitive data collection or waiting time)	6

n = 132.

In the first open-ended item (the importance of the physiology laboratory), almost all students reported laboratory work as very important for learning difficult concepts and physiological processes (e.g., action potential), as the hands-on experiences gave a more concrete idea of the learning content and made the content easier to remember (see Table 3). This was illustrated by the following comments:

> The textbook explain the theory and the lab work visualize it, and this makes it easier to understand–and remember.

> Practical examples provide a much better understanding of the theory.

Only a very few students did not highlight the importance of laboratory work for their own learning, e.g.:

> People are learning in different ways. Doing practicals does not reinforce my learning.

Twelve students highlighted the insights into research methods as an important outcome of performing laboratory work, e.g.:

> It [lab work] provides insight into how research can take place, and it is therefore an important element when you have to decide in which area you want to do research.

> Lab work is important because it gives knowledge about procedures in the lab.

Motivation was only mentioned by six students in the open-ended question, e.g.:

> . . . it is also that part of the course which is most exciting.

> It makes the subject more interesting.

Most student responses to the question about the best experience concerned learning by performing practical work (n = 41), e.g.:

> . . . I did not understand [the theory] on beforehand and during the lab I suddenly understood.

For 21 students, the best experience was to discuss procedures and findings with the instructors and teachers, e.g.:

> Individual supervision by the teachers provides a better understanding of the lab work.

For a minority of the students, the best experiences in the laboratory were related to achieving good laboratory results (n = 13), learning from writing laboratory reports (n = 5), and performing perform physiological measurements on their own bodies (n = 3).

Missing data were mentioned by 33 students as the most negative experience in the laboratory, whether it was due to apparatus defects or human errors. Thirty-three students mentioned work organization (too many students, distribution of duties, and time pressure) and monotonous workflow (repetitive data collection and waiting time) as the most negative experiences.

DISCUSSION

The purpose of the present study was to investigate how laboratory work influences student motivation in physiology. We handed out a self-report questionnaire to assess the level of student interest, perception of effort/importance, and self-efficacy and tested the correlation of the subscales with the students' exam performance to see if motivation for laboratory work could predict academic performance. In addition, we posed three open-ended questions to capture student voices about how they experienced the laboratory work.

The results show that students found the laboratory work highly interesting. The very positive responses might indicate a ceiling effect, which occurs when a measure possesses a distinct upper limit for potential responses, and a large concentration of participants score at or near this limit.

Interest is known to increase alertness, direct attention, enhance concentration, facilitate problem-solving strategies, enhance effort and persistence, and motivate initiatives in which students seek out, investigate, and manipulate new and needed information (13). Interest is thus a reliable predictor of positive student outcomes, such as skill development, knowledge acquisition, and achievement (36). Since interest replenishes the motivational and cognitive resources of students, we had expected correlation between self-reported interest and academic performance in terms of exam performance at the end of the course. No significant correlation was found, however. Laboratory work might trigger interest in many ways; hands-on animal laboratory experiences, for instance, have previously been suggested as an important factor of engaging students in physiology (7, 30, 44), and Dohn et al. (11) have found that hands-on experiences with live animals in laboratory trigger student interest. Since our interest items are concerned with laboratory work in general, we cannot identify the various triggers for interest. It is likely that students refer to various incidences and experiences when filling the questionnaire. Thus, we attribute the absence of correlation to the fact that there was little alignment between the interesting elements of practical work and the exam questions.

Students valued their effort during laboratory work and the importance of the laboratory work relatively high. In addition, most students in our study reported high self-efficacy, which suggest that they believed in their capabilities. Self-efficacy was positively and significant correlated with academic performance, which suggests that self-efficacy relates in important ways to cognitive factors contributing to students' learning (29). However, no significant correlation was found between the motivation subscale effort/importance and academic performance. Again, we ascribe the absence of correlation to the fact that there was little alignment between self-reported effort and importance in laboratory work and exam tasks. Alternatively, it is also necessary to recognize that self-reported effort in practical work (as evidenced by the students' apparent involvement with the objects, materials, and phenomena) does not imply cognitive engagement with all of the intended ideas or concepts. According to Abrahams (1), students can be fully engaged in what they were doing without being cognitively engaged with the task in a manner that would have been necessary for them to have learned what faculty members intended.

Most students described laboratory work very important for learning difficult concepts and physiological processes (e.g., action potential), as the hands-on experiences gave a more concrete idea of the learning content and made the content easier to remember. A few comments around the best experiences in laboratory were oriented toward specific learning goals, for example, "To understand my own metabolism so I know why I don't gain weight." It should be noted, however, that these beliefs do not necessarily reflect students' actual learning in physiology. Yet, despite these findings, a number of science educators have raised questions about the effectiveness of practical work for learning science, and findings from research into the effectiveness of practical work in enhancing the development of conceptual understanding in science remain ambiguous (2, 17). In this context, it has been proposed that it is necessary to introduce students to the relevant scientific concepts before they undertake any practical work (27). The positive student comments in our study may reflect that this indeed was the case, for example, ". . . I did not understand [the theory] on beforehand and during the lab I suddenly understood."

Missing data (no matter if the reason was apparatus or student failures), work organization (too many students, distribution of duties, and time pressure), and monotonous workflow (repetitive data collection and waiting time) were mentioned as negative experiences by the students. Missing data due to student failure, for example, might lower self-concepts beliefs and outcome expectations (43). Although missing data, work organization, and monotonous workflow are likely to influence student motivation negatively, we have only vague ideas of their influence since we have limited our study to measure students' experienced interest as well as their willingness to engage (effort) and their confidence in understanding (self-efficacy). The negative experiences had apparently no impact on students' interest.

According to Hofstein and Lunetta (18), laboratory activities have the potential to enhance constructive social relationships. The social environment in a university laboratory is usually less formal than in a conventional lecture; thus, the laboratory offers opportunities for productive, cooperative interactions among students and with faculty members that have the potential to promote an especially positive learning environment. The learning environment depends markedly on the nature of the activities conducted in the laboratory, the expectations of the faculty members and students, and the collaboration and social interactions between students and faculty members. In our study, several students highlighted the communication with faculty members as the best experience in the laboratory. The organization of the laboratory work provided the opportunity to ask questions and discuss with faculty members in a more informal way than in front of class in a lectures, which likely increase students' confidence and intrinsic motivation (35).

The presented results have potentially important implications for classroom practice as biology students find laboratory exercises highly motivating, despite their different personal interests, preferences, and career goals. Thus, the laboratory has a central role in physiology teaching and learning. It is, however, important to point out that limited laboratory equipment and time restrictions may have negative impact on students' motivation, as indicated by students' negative statements in the Lab Motivation Scale. Although laboratory work is time consuming and expensive, our findings suggest that investigations with live organisms should not be replaced entirely by other nonpractical approaches, for example, video demonstrations or computer simulations. Video materials can juxtapose images of real events and processes with theoretical ideas and constructs, for example, by showing an action potential alongside an atomic-level representation of the process. Similarly, well-designed computer-based teaching materials, including simulations, animations, and other kinds of modeling activities, can also be very useful in helping students to operate in the domain of ideas (26). Such materials provide a useful preparation for an observation of a real phenomenon, by directing the students' attention to specific features of the real event. However, they cannot wholly replace first-hand practical experience. The reason is that real laboratory events are important for students' academic motivation and learning. Students who are interested and believe they are able and that they can and will do well are much more likely to be motivated in terms of effort, persistence, and behavior than students who believe they are less able and do not expect to succeed. There also is good evidence to suggest that these motivated students will also be more cognitively engaged in learning and thinking than students who doubt their capabilities to do well (19, 29). This highlights the importance of laboratory work to support students' motivation and learning in physiology.

There are limitations to these findings, however. All motivation components of the students were measured with a self-report instrument. Self-reports can be used effectively to measure student perceptions of motivation, but the results need to be replicated with other measures, such as structured interviews or behavioral measures. Clearly, more research is needed on the multivariate relationships between student motivational orientation and academic performance in the laboratory context. The open questions included in the self-report may reveal something of the specific reasons explaining students' motivation in laboratory work that cannot be grasped from the analysis of the closed items.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

N.B.D. conception and design of research; N.B.D., A.F., J.O., P.T.M., and H.M. performed experiments; N.B.D. analyzed data; N.B.D. interpreted results of experiments; N.B.D. prepared figures; N.B.D. drafted manuscript; N.B.D., A.F., J.O., P.T.M., and H.M. edited and revised manuscript; N.B.D., A.F., J.O., P.T.M., and H.M. approved final version of manuscript.

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