The Implementation of Inquiry-Based Learning Activities in an Introductory Animal Science Course

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Abstract

Inquiry-based learning (IBL) is a student-centered teaching technique that promotes engagement through higher-order thinking, collaboration, and creativity. This study examines the impact of IBL levels on students' interest, motivation, and engagement. Three levels of IBL (traditional, structured, and guided) were implemented in an introductory animal science laboratory session at three time points during the Fall 2021 semester. Students (n=169) were divided among five laboratory sessions and then randomly within each lab, students were then divided into six groups using a Latin square arrangement. During each time point, students completed 20-minute case scenario activities utilizing one of three IBL levels. Inquiry levels were differentiated by the instruction, information, and supplies provided to students. At each time point, students self-reported their situational interest, motivation, and engagement on a Likert scale. Across all IBL levels, students experienced high levels of attention demand, identified regulation, and personal effort and no differences were seen between IBL levels. Although limited to one course, our findings suggest that IBL activities promote interest, engagement, and motivation, which could generate long-term student engagement and investment in course content. Future research should juxtapose IBL and traditional teaching methods to further examine the impact in additional formats and subjects.

Keywords: inquiry-based learning, interest, motivation, engagement

Learner-centered teaching (LCT) is becoming increasingly popular in classrooms as teachers move away from a traditional teacher-centered learning model. LCT balances the power dynamic between students and instructors, as the instructors grant students more responsibility, creativity, purpose, and a greater role in their own learning (Wright, 2011). In doing so, instructors transition from an instructor to a guided facilitator, which allows them to provide mentorship and develop relationships with students. LCT is beneficial within a classroom as it fosters interpersonal relationships among students and with the instructor, prompts active learning and participation, and increases students' creativity and critical thinking (Abdelkader et al., 2019). Additionally, LCT creates an emphasis on the learner's identity by adapting to different students' learning styles (KeenGwe, 2009). Examples of LCT activities include problem-based learning, project-based learning, inquiry-based learning (IBL), and other hands-on learning formats.

One example of LCT, IBL, fosters a learning environment where students follow scientific processes to construct scientific knowledge (Keselman, 2003). A common IBL activity example is engaging students in the scientific process. During this process, students are guided by a question and prompted to hypothesize the outcome, perform the experiment, analyze data, draw conclusions, and present results. This grants students the responsibility of learning and understanding the material in a self-sustained and propelled manner, in comparison to traditional lecture instruction where students do not play as active of a role (Panasan & Nuangchalerm, 2010). IBL engages students' creativity by providing time, content, and materials to create and construct their own understanding, findings, and response to a scientific question. Meanwhile, the instructor transitions to a facilitator role within the classroom and helps to guide, mentor, and coach the students (Casswell & LaBrie, 2017). As a result of the required student self-motivation, IBL requires greater student engagement and effort to complete the process and comprehend the material (Pedaste et al., 2015). Additional benefits of IBL include an enhanced student learning experience, curiosity, engagement, motivation, and retained knowledge (Artayasa

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et al., 2017; Caswell & LaBrie, 2017). Furthermore, IBL also enhances an instructor's experience through increased interaction, collaboration, and mentorship with students (Spronken-Smith, 2012).

The Four Levels of Inquiry-Based Learning

There are contrasting ways to implement and include IBL in a classroom. Lederman outlines four levels of IBL: traditional, structured, guided, and open. Each level expands on the previous, and as the levels increase, students are given less instruction and are prompted to use higher order critical thinking skills to further brainstorm, explore, and develop a deeper concept of the learning material and objectives (Lederman, 2009).

Traditional inquiry is the primary level where students receive complete guidance and instruction for the entire scientific process. For example, students are provided with a question, procedure, predicted answer, and conclusion. They are also provided with rationales as to why the results occur and what these findings mean in a larger context. In comparison to other levels, student's content retention has been notably the lowest in traditional IBL (Artayasa et al., 2017).

Structured inquiry is the next level, and like the traditional level, students receive a scientific question and procedure to follow. In contrast to traditional, students instead are asked to oversee the process of running the experiment, collecting data, and analyzing the data to form conclusions. Like traditional, structured is linked to lower stress levels and lower-critical thinking skills in comparison to higher levels of IBL. Overall, this level is still considered an easy level for students to follow and understand (Bunterm et al., 2014).

Next, guided inquiry is facilitated when the instructor provides a research question and asks the students to create and perform a procedure and draw conclusions. Some benefits of this higher-order critical thinking level include improved content knowledge, strengthened processing skills, increased scores on assessments, and improved interest as opposed to lower-order thinking (Bunterm et al., 2014; Cresswell & Loughlin, 2017). Additionally, students develop the ability to expand their findings to related research and increase their perception and understanding of the conclusion (Hyland et al., 2021).

Finally, open inquiry is the most advanced and active level of IBL where students create their own questions, design an experimental procedure, gather data, and interpret the results to formulate a conclusion. This level promotes satisfaction in students, furthers growth in comparison to previous levels, and prompts a greater sense of involvement (Sadeh & Zion, 2011). Additionally, open inquiry is linked to an increased understanding of learning outcomes and increased test scores. It also promotes diversity in students' opinions and experiences, increases preparation time, creates greater student perception, and improves time efficiency (Sadeh & Zion, 2009; Artayasa et al., 2017). However, this level may not be suitable for students with lower levels of confidence, lower attitudes within the course, or lower motivation, as they will need more instructor support to succeed with this level and require more guidance and feedback (Berg et al., 2003).

Theoretical Framework

Following the implementation of active learning programs, it is important to evaluate whether student interest, engagement, or motivation change. Situational interest is critical to consider because it can lead to prolonged personal career interests for students within the course (Hidi & Renninger, 2006). Interest has four phases, during which the student develops and deepens their interest in the subject. Students work through this process by first being introduced to material that sparks interest (triggered situational interest), then focusing on a project they find interesting over a period (maintained situational interest), reengaging with the material (emerging individual interest), and continuing to reengage and spark interest over longer time spans (well-developed individual interest) (Hidi & Renninger, 2006).

Student motivation is important to evaluate when implementing IBL activities as it can clarify and explain behaviors. For instance, a student might invest energy in a project so they can earn a better grade to pursue their future career aspiration. When students experience this motivation, their experience improves, stress decreases, relationships improve, and learning and creativity improve (Abdelkader et al., 2019). The Self-Determination Theory (SDT) presents frameworks to explain factors contributing to motivation and wellness in academic settings (Ryan & Deci, 2020). The theory presents a progression of motivations from amotivation, to extrinsic forms, to intrinsic motivation. Intrinsic motivation is doing a task for satisfaction or enjoyment, extrinsic motivation is performing a task for external rewards or separable outcomes, and amotivation describes seeing no value in completing a task.

Engagement can be measured to explain students' social investment and interactions. As students become more engaged in the classroom, they transition from passive to active to constructive to interactive learners, as indicated by the ICAP framework (Chi & Wylie, 2014). This shift in perspective results in increased learning. Engagement can be measured by using social cues and indicators, such as how students perceived their group interactions and relationships with their instructors (Wiggins et al., 2017).

Purpose

The purpose of the study was to examine differences in students' interest, motivation, and engagement after experiencing three levels of IBL activities. Our study was guided by the following research question: *Does student's self-reported interest, motivation, and engagement differ between IBL levels?*

Methods

Participants and Context

This study was conducted with a sample population of 169 undergraduate students enrolled in an introduction to animal agriculture course in the fall of 2021. The 16-week course format was comprised of two 50-minute lectures and one 110-minute laboratory session each week. Students were randomly placed in one of five laboratory sessions, and each session ranged in enrollment from 32 to 45 students. The class consisted primarily of first-year students (80.7%) and second-year students (13.3%), with the remaining 6.0% comprised of third and fourth-year students. Most students (95.3%) were enrolled in a program within the college of agriculture, and 94.7% were majoring in animal science.

Study Design

All procedures for this study were approved by the university's institutional review board (IRB-2021-1126). The study examined three primary levels of IBL: traditional, structured, and guided. Each inquiry level was designed using Llewellyn's proposed inquiry cycle which has six unique stages (Artayasa et al., 2017). The stages are as follows: inquisition, acquisition, supposition, implementation, summation, and exhibition. Each stage includes the expectations of the instructor and the student (Artayasa et al., 2017). The three levels were applied to each laboratory session's topic. Table 1 includes a description of the three IBL levels.

The experimental periods were conducted during the laboratory sessions in weeks eight (T1), eleven (T2), and thirteen (T3). The topics for each of the three IBL experimental periods included animal health, horse management, and animal behavior, respectively. Each week, the content and learning outcomes were standardized across the three different IBL levels. An example of the worksheets provided to students of different IBL levels is included in Appendix 1.

Prior to the first experimental period, students in each lab time were randomly divided into six groups. These groups remained consistent among experimental periods and consisted of five to eight students. Within each lab time, two groups were assigned to one of the three IBL levels. Table 2 provides a description of the Latin square arrangement used in this experiment. Additionally, the three IBL levels were assumed to be independent of each other and thus were arranged in random order.

Within each experimental period, groups were given twenty minutes to complete a case-based scenario. Each group was provided resources custom to their inquiry level (Table 1). Groups worked through the scientific process with the following sections: question, hypothesis, procedure, results, and conclusion. After 15 minutes, the instructor warned students that they had five minutes remaining. After the 20 minutes ended, the instructor asked students to stop what they were doing and provided groups with a QR code to access the Qualtrics survey questions.

Instrumentation

Situational interest was measured using the Situational

Table 1.

Description of inquiry levels

Treatment	Description	Resources Provided
Traditional	1. Instructor provides a question 2. Students hypothesize 3. Students select answers to test 4. Student follow instructor's procedures 5. Students collect dat, with knowledge of a predicted result and conclusion 6. Instructor presents results	Background Information Scientific Process Worksheet Research Question Materials Methods Predicted Conclusion
Structured	1. Instructor provides a question. 2. Students hypothesize 3. Students select answers to test 4. Student follow instructor's procedures 5. Students collect/present data and draw conclusions 6. Students presents results	Background Information Scientific Process Worksheet Research Question Materials Suggested Methods
Guided	1. Instructor provides a question. 2. Student hypothesize 3. Students select answers to test 4. Student develop and follow procedures 5. Students collect/present data and draw conclusions 6. Students presents results	Background Information Scientific Process Worksheet Research Question **students must ask instructor for materials

Note. *The numbers are corresponding to the steps which are as follows 1. inquisition, 2. acquisition, 3. supposition, 4. implementation, 5. summation, and 6. exhibition.
Breakdown for each of the three levels of inquiry-based learning of the description and resources provided in correspondence with Llewelyn's learning cycle (Artayasa et al., 2017).

Table 2.

Latin square treatment arrangement

Group #	Period 1 (T1) October 15th	Period 2 (T2) November 5th	Period 3 (T3) November 19th
1	Structured	Traditional	Guided
2	Traditional	Guided	Structured
3	Guided	Structured	Traditional
4	Structured	Traditional	Guided
5	Traditional	Guided	Structured
6	Guided	Structured	Traditional

Note. The Latin square arrangement for the group assignments to each of the three inquiry-based learning levels across three periods within each laboratory section of an introductory to animal science course.

Interest Scale (SIS) developed by Chen et al. (1999) and consisted of the following subscales: exploration intention, instant enjoyment, novelty, attention demand, and challenge. The Situation Motivation Scale (SIMS) was used to measure motivation to explain the student's perspective and reasoning and consisted of the following subscales: intrinsic motivation, identified regulation, external regulation, and amotivation (Guay et al., 2000). Finally, ASPECT (Assessing Student Perspective of Engagement in Class Tool) was used to measure students' self-reported engagement and consisted of the following subscales: value of group activity, instructor contribution, and personal effort (Wiggins et al., 2017). Each of the respective surveys was validated by their sourced journal publication. The range of Cronbach's alpha for the SIS was 0.82-0.94, the SIMS was 0.82-0.89, and the ASPECT was 0.30 to 0.94.

During each experimental period, self-report measures were collected using a Likert scale and used to quantify situational interest (1-5), situational motivation (1-7), and engagement (1-6). The Likert Scale used for the SIS described the following response choices: strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree. The Likert Scale used for the SIMS described the following response choices: corresponds not at all, corresponds very little, corresponds a little, corresponds moderately, corresponds enough, and corresponds a lot. The Likert scale used for ASPECT described the following response choices: strongly disagree, somewhat disagree, slightly disagree, slightly agree, somewhat agree, and strongly agree.

All the questionnaires were compiled into one via the Qualtrics survey platform (Qualtrics, Inc. Provo, UT), and were administered at the end of each experimental period. Students completed the questionnaire using mobile phones, laptops, or tablets. The survey was anticipated to take between five to ten minutes to complete, and students typically completed the survey within five minutes. Response rates for each experimental period were n=88.2%, n=81.7%, and n=81.1%, for T1, T2, T3 respectively.

Qualitative data was also collected regarding what students found engaging, disengaging, and what they would change about the IBL activity. Students were asked to provide short responses to each of the qualitative questions.

Statistical Analysis

The quantitative data were analyzed using SPSS (SPSS Inc., Chicago, IL, USA). The data were analyzed using one-way ANOVA test to see if significant differences existed between the IBL levels and subscales in each of the instrumentations. Furthermore, multivariate analysis with pairwise comparisons were run to calculate the estimated marginal means for each of the subscales. Finally, correlations were calculated to determine if relationships existed between data, where groups refer to the assigned team that the students worked on during the IBL activities, period refers to the experimental time periods (T1, T2, and T3) and the type of inquiry level (traditional, structured, and guided). Qualitative data were analyzed using inductive coding. Student responses were sorted and grouped into common themes (Linneberg & Korsgaard, 2019).

Results

Situational Interest

The estimated marginal means for the three treatments for the SIS subscales and the overall scale average are included in Table 3. While there were no significant differences between the IBL levels and SIS subscales, attention demand and exploration intention had the highest estimated marginal means with a range between 4.18 to 4.33 and 4.03 to 4.20, respectively, which means that students' average responses fell between the two response choices of somewhat agree and strongly agree regarding the statements. The high estimated marginal mean for attention demand indicated that students were engaged and experienced enjoyment during the activities. Subsequently, the high exploration intention indicated that students were

Table 3.

Estimated marginal means for Situational Interest Scale (SIS) subscales during each of the three inquiry levels

SIS	Traditional	Structured	Guided
Exploration Intention	4.03	4.18	4.20
Instant Enjoyment	3.97	4.14	4.11
Novelty	3.98	3.91	3.93
Attention Demand	4.18	4.33	4.22
Challenge	2.45	2.42	2.57
Average	3.72	3.80	3.81

Note. Estimated marginal means of situational interest for students (n=169) within an introductory animal science course across three level of inquiry-based learning. The Situational Interest Scale was measured using a Likert scale of 1 to 5. 1 corresponded to strongly disagree and 5 corresponded to strongly agree.

Table 4.

Correlation Situational Interest Scale (SIS)

SIS	Exploration Intention	Instant Enjoyment	Novelty	Attention Demand	Challenge	SIS Average
Lab Time*	0.039	0.100**	0.127***	0.112**	-0.78	0.076
Group	-0.100*	-0.089	-0.088	-0.128***	-0.087	-0.132***
Period	-0.077	0.122*	0.026	0.055	-0.075	0.011
Inquiry Level	0.092	0.063	-0.023	0.018	0.051	0.054

Note. * Lab time refers to the time of day that the lab was conducted
** Correlation is significant at the 0.05 level (2-tailed)
*** Correlation is significant at the 0.01 level (2-tailed)
Correlation values for student's situational interest scale's subscale responses within an introductory animal science course laboratory in relation to lab time, group, period, and inquiry level. Asterisks represent significant differences as denoted in table.

stimulated by the activity and curious to learn more about the material presented (Chen et al., 1999). Challenge had the lowest estimated marginal mean with a range of 2.42 to 2.57, which fell between an average response of somewhat disagree and neither agree nor disagree regarding the statements. Lower challenge estimated marginal means might indicate that students did not feel as though they had to use higher-order critical thinking skills to solve the activity.

Correlation values were calculated between the time of day the lab was conducted, group, period, and inquiry level to the SIS subscales (Table 4). There was a significant correlation between lab time and instant enjoyment, novelty, attention demand, and total interest. This indicates that the lab time or student dynamics within the groups potentially impacted or was related to their experience and situational interest within these subscales. Significance was also found between group and exploration intention, attention demand, and SIS average, indicating that their social interactions could have impacted their situational interest.

Situational Intrinsic Motivation

The estimated marginal means from the multivariate analysis of the SIMS questionnaire and its respective subscales are included in Table 5. While there were no significant differences between the three levels of IBL and the subscales within SIMS, identified regulation received the highest estimated marginal means with a range of 5.07 to 5.11, indicating that students agreed with the statements and were selecting "corresponds enough" and "corresponds a lot" regarding the prompts. This meant that students valued their participation in the activity and felt as though they were choosing to complete the activity (Guay et al., 2000). Furthermore, amotivation had the lowest estimated marginal means with a range of 2.66 to 2.72, implying that responses ranged from "corresponds very little" to "corresponds a little" when prompted by the statements. This indicates that the students rarely felt a disconnect between their participation and outcomes in the activity (Guay et al., 2000).

Correlation values were calculated between the time of day that the lab was conducted, group, period, and inquiry level, and the SIMS subscales using SPSS (Table 6) (SPSS Inc., Chicago, IL, USA). Significant correlation values were found between amotivation and lab time, meaning that the student's motivation may be dependent on when their lab time was and/or the environment/peer students within their lab time. A significant correlation was found between group and intrinsic motivation, identified regulation, and SIMS average. Period was significant with intrinsic motivation, meaning that the laboratory topic may have influenced how interested and internally motivated the students were to engage in the activity.

Student Engagement

The estimated marginal means for the ASPECT subscales are reported in Table 7. The personal effort was the highest estimated marginal mean with a range of 5.10 to 5.23, meaning students responded with somewhat agree to strongly agree. This high response represents positive social interactions when completing the IBL activities. Students were aware of their thought processes and motivations, as well as the course's influence and student obligation when completing the case scenarios (Wiggins et al., 2017).

Table 5.

Estimated marginal means Situational Motivational Scale (SIMS)

SIM	Traditional	Structured	Guided
Intrinsic Motivation	4.93	4.99	4.94
Identified Regulation	5.07	5.11	5.15
External Regulation	4.25	4.39	4.37
Amotivation	2.72	2.66	2.70
Average	4.24	4.29	4.29
Average	3.72	3.80	3.81

Note. Estimated marginal means of motivation for students (n=169) within an introductory animal science course across three level of inquiry-based learning. The Situational Motivational Scale was measured using a Likert scale of 1 to 6. 1 corresponded to strongly disagree and 6 corresponded to strongly agree.

Table 6.

Correlation Values Situational Motivation Scale (SIMS)

SIMS	Intrinsic Motivation	Identified Regulation	External Regulation	Amotivation
Lab Time	0.052	0.061	-0.088	-0.159**
Group	-0.126**	-0.115*	-0.47	-0.010
Period	0.124*	0.021	-0.032	0.041
Inquiry Level	0.004	0.029	0.036	-0.007

Note. * Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)
Correlation values for student's situational motivational scales subscale responses within an introductory animal science course laboratory in relation to lab time, group, period, and inquiry level. Asterisks represent significant differences as denoted in table.

Table 7.

Estimated Marginal Means Assessing Student Perspective of Engagement (ASPECT)

ASPECT	Traditional	Structured	Guided
Value of Group Activity	4.96	5.00	4.95
Instructor Contribution	4.84	4.90	4.98
Personal Effort	5.11	5.23	5.10
Average	4.97	5.04	5.01
Average	4.24	4.29	4.29

Note. Estimated marginal means of motivation for students (n=169) within an introductory animal science course across three level of inquiry-based learning. The Situational Motivational Scale was measured using a Likert scale of 1 to 6. 1 corresponded to strongly disagree and 6 corresponded to strongly agree.

Correlation values are reported in Table 8 for the ASPECT questionnaire between the lab time, group, period, and inquiry level, value of group, instructor contribution, personal effort, and average. There was significance found between lab time and all the subscales within ASPECT. This indicates that the time of lab, environment within that lab section, or peer interactions within the lab may have affected their perceived engagement during the activity. Additionally, there was significance found between the group and instructor contribution and personal effort. This indicates that the group of students differed in their views of instructor contribution and personal effort in the activity. There was also significance found between the period and instructor contribution, meaning the lab topic was significant in how students viewed the instructor's contribution.

Qualitative Data

Students were asked what they found engaging, disengaging, and what could be improved about the IBL activity. Common themes identified included hands-on learning, research and experimentation, group related experiences, instruction, difficulty, time constraints, content knowledge, and activity specific feedback. The number of responses that were grouped into a category was then divided by the total number of responses across the three periods, N=149 for T1, N=138 for T2, and N=137 for T3. When asked what they found engaging, 34.4% of students reported the activities hands-on elements. For example, one student stated, "I found it engaging to do hands on work that represents real life situations". Additionally, 26.7% cited the testing and research aspects, and 11.1% reported the group interactions increased engagement with the activity.

A small group of students (17.0%) reported that the instructions resulted in feelings of disengagement. Some of the students struggled with the instructional format, and for instance, one reported, "Today's activity was disengaging because there was not a lot of instruction, so I was a little confused at the beginning, but then got the grasp of it soon after." This could be a result of the minimal instruction that was provided. This was because instruction needed to remain consistent among lab section times and to do this, instructions were listed on handouts at their group stations. Group interactions also played a role in why students found the activity disengaging, as 8.0% of students cited their group members as a reason for disengagement. For instance, one student stated, "I just felt like there were too many chefs not enough cooks in this activity. Everyone in my group wanted to have a say, and it became more confusing the more opinions there were in the group".

When asked what could be improved, 34.0% of students didn't have any suggestions. However, 13.4% provided responses related to instruction, and 12.7% reported recommendations related to the specific activity. One example of the improvements suggested was, "Explain a little more on what we are doing because my group was confused a little bit at first." Another example related to instruction was, "Have someone come to explain what we are supposed to do exactly." These responses are in accordance with the procedure, where students among the three IBL levels were given little briefing to begin the activity.

Table 8.

Correlation Values Assessing Student Perspective of Engagement (ASPECT)

ASPECT	Value of Group	Instructor Contribution	Personal Effort	ASPECT Average
Lab Time	0.158**	0.151**	0.212**	0.192**
Group	-0.071	-0.009	-0.106*	-0.068
Period	0.063	0.102*	-0.011	0.056
Inquiry Level	-0.004	0.064	-0.002	0.022

Note. * Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)
Correlation values for student's ASPECTs subscale responses within an introductory animal science course laboratory in relation to lab time, group, period, and inquiry level. Asterisks represent significant differences as denoted in table.

Discussion

Situational Interest

Understanding students' interest and motivation is important to provide insight when developing course activities that impact the learning process and promote engagement with the course content. In comparison to other forms of motivation, interest focuses on the content of learning and can be thought of as a relationship formed or realized between a person and an object as a result of experience with an activity. Situational interest is important and valuable to measure as it can provide insight into if an experience can prompt a student's interest. This may inspire the student to learn more about a subject matter and develop an individual personal interest in the topic (Chen et al., 1999). Individual interest is stable high interest toward a content area and can influence the formation of motivation (Schiefele, 2009). Increased development of individual interest is linked to increased classroom achievement and contributes to career preference (Rotgans & Schmidt, 2017).

Situational interest was measured in our study to examine students' emotional responses to an activity and to determine if IBL promotes long-term stable personal interest in the content area (Schiefele, 2009). Students in our study reported an overall positive experience with the lab's IBL activities. Students wanted to explore the content area (exploration intention). Exploration intention is beneficial because it is what attracts students to engage in an activity. Additionally, exploration intention and instant enjoyment are indicative of whether a student will reflect emotional and cognitive preference toward the activity (Chen et al., 1999). Students in the course enjoyed the activity (instant enjoyment) and indicated the activity was something new, complex, or unexpected (novelty). This gap in their knowledge will attract them to be curious to learn something new. Students were also attentive (attention demand) during the activity, which indicates they perceived the activity as engaging and positive (Chen et al., 1999; Schiefle, 2009). Despite the increased feelings of interest, students reported not feeling challenged during the activity, which could have hindered students' attraction to engage in the activity (Chen et al., 1999).

Interestingly, we did not observe differences in SIS subscales across the three IBL levels. It was hypothesized that there would be differences in situational interest between IBL levels due to the differing amounts of self-instruction, facilitation, difficulty, freedom, and creativity. These differentiating factors between the levels were hypothesized to be especially noted in the exploration intention, attention demand, and challenge subscales. IBL promotes increased student interest regarding their attitudes towards content, learning atmosphere, commitment, and challenge. It is possible that the measures used in this study were not sensitive enough to capture individual differences (Wang et al., 2015).

Additionally, the case scenarios were rooted in hands-on activities, which are linked to increased student interest. This interest was then further amplified by the activities' relevance and application to everyday life, which in this case would be to their future careers as animal scientists (Jocz et al., 2014). Students found the hands-on and experimentation aspects of the IBL activities to be the most engaging, indicated by the following representative quotes:

"I liked the hands-on experience of feeling like I was doing real world events."

"I felt like this activity allowed each group members to actively contribute. Additionally, real-life scenarios are personally the best way for me to learn the material especially if I am presenting the tests myself."

Furthermore, these hands-on and experimental activities can stimulate initial interest and lead to a prolonged interest and maintained personal interest in the subject matter. Stimulated interest may guide students' learning (Chen et al., 1999). This interest is valuable and rare as personal interest is individual to each student. It is formed from previous knowledge and values. Therefore, as an educational system, it can be challenging to find avenues to promote personal interest among all students, but this promotion is crucial as it will propel students forward in learning more about a subject matter (Chen et al., 1999).

Situational Motivation

Students with greater levels of autonomy, or choice, have more positive experiences in the classroom. Previous studies have linked these autonomous experiences to improved perceived competence, increased interest and satisfaction, lower anxiety or negative affective states, and improved course retention rates (Black & Deci 2000). Furthermore, increased levels of autonomy are associated with intrinsic motivation and self-regulation. The SIMS subscales are supported by the SDT (Ryan & Deci, 2020), which explains the sense of choice one feels when choosing to participate in an activity (Guay et al., 2000).

While there were no significant differences between the three levels of IBL activities, the data supported the abilities of IBL activities to motivate students. Our students reported high intrinsic motivation, meaning they experienced instant enjoyment and satisfaction internally, which is why they engaged with the activity (Ryan & Deci, 2020). This level of intrinsic motivation predicts a future persistence to continue engaging with the activity content matter. Additionally, intrinsic motivation is the highest associated subscale with positive outcomes within the SDT (Guay et al., 2000). Our students also responded with high levels of extrinsic motivation, as shown by the high levels of identified regulation and external regulation. The high levels indicate that students found it rewarding to complete the IBL activities. The reward could be their grade in the course, compliance with the classroom environment and instruction, or personal choice in the matter (Guay et al., 2000; Ryan & Deci, 2020). This combination of both high intrinsic and extrinsic motivation is shown to be an adaptive profile for students who excel both academically and emotionally (Corpus et al., 2016).

In contrast to the other subscales, amotivation can indicate that students feel activities are not relevant, important, or necessary to be competent in the course (Ryan & Deci, 2020). Students may also feel helpless or confused with the task, which results in lack of motivation (Guay et al., 2000). Students in our study reported low amotivation, indicating that during the IBL activities, students felt as though they had a purpose, found the activities meaningful and pleasant, and were gaining something from their participation. Our findings suggest that, based on SDT, students felt their basic needs of autonomy, relatedness, and competence were met. The IBL activities facilitated motivation and an enhanced autonomy-supportive learning experience (Ryan & Deci, 2020).

Engagement

Students in our study reported high value of the activity, personal effort, and instructor contribution. Furthermore, students reported a high value social experience with the activity, meaning that the communication and collaboration among their group members improved their understanding of the material. Additionally, they considered their group member's perspectives when completing the activity, which aligns with previous research stating that IBL increases students' teamwork skills (Al-isamily et al., 2018). They also reported high personal effort, indicating they were aware of others' thoughts and opinions, acknowledged their personal motivation, and were personally choosing to engage in the activity (Wiggins et al., 2017). The last factor that was measured was instructor contribution, for which students reported high values as well. This indicates the students had positive perceptions of the instructor's preparation, summative assessments, and instruction (Wiggins et al., 2017). While there were no differences between the three IBL levels, the student's perception of their social engagement indicated that the activities supported positive social interaction. This interaction fostered a successful active learning activity in which students transitioned from passive to interactive learners. Active learning classrooms can promote students' proficiency and perceived value of the learning experience (Wiggins et al., 2017).

Independence of Inquiry-Based Learning Levels

Analysis of the correlation data revealed the possibility that the order in which students experienced the three IBL levels may impact their interest, engagement, and motivation. This means that a student's experience with IBL activities could affect their future expectations and perceptions on different IBL levels. A recent paper by Chaudhary (2021) suggests that scaffolding, an educational technique that explains the importance of slowly transitioning to active teaching styles, may be necessary to smooth transitions for students and promote success. This relates to IBL because students may need this scaffolding support for them to feel comfortable and be able to succeed in classrooms with less instructional guidance. Furthermore, this could explain why in this study, there no significant differences in interest, motivation, and engagement across the three levels of IBL. The lack of significance could be attributed to students not feeling prepared for the higher level of IBL or that they experienced negative affective states such as anxiety and/or confusion. This could further indicate that the sequence of IBL levels affects students' interest, motivation, and engagement.

Limitations and Future Applications

To the best of our knowledge, this is one of the first papers to examine the impact of IBL levels on student interest, engagement, and motivation. We hypothesized that there would be differences among the three IBL levels because of the different amounts of initiative, creativity, collaboration, problem-solving, critical thinking skills, and time management required from student-centered learning when compared with teacher-centered instruction.

Some potential limitations in the study could have been that there was not enough difference between the three IBL levels to impact students. Additional limitations may be that students did not experience the different levels for sufficient time lengths, or the measures used were not sensitive enough to detect the changes. Students could also view other levels of inquiry within the same laboratory, which could have influenced their decisions. The different social dynamics among groups within lab sessions and lab sessions could have also impacted how they viewed the different levels. Additionally, not all the students were present for all three levels thus, the group sizes fluctuated. The timing of the study, related to the COVID-19 pandemic, may have influenced students' response to the activities. The majority of students in the class were first-year students who may have spent one to two years prior to enrolling at [university] engaging in online learning and were not as accustomed to in-person student-centered environments.

Future studies should collect a baseline measurement of interest, motivation, and engagement when interacting with traditional teacher-centered instructional styles in contrast to student-centered learning. This would allow differences to be captured to compare IBL not only to traditional methods but also compare the teacher-centered instructional results among the different IBL levels. The location and environment should also be considered in future studies to limit outside distractions.

Overall, the IBL model is valuable because it assists in developing higher order thinking skills. These skills are necessary for students to analyze problems, brainstorm, create hypotheses, follow and/or manage procedures, draw conclusions, and reflect on their inquiry process successfully and independently. These abilities are crucial for students to develop before they step into their respective careers, as these abilities will aid them in transitioning to the workforce and help them excel in their careers. (Al-Isamily, 2018).

Inquiry-based learning has commonly reported benefits such as decreased student's self-reported perceived stress, increased retention of knowledge, and increased interest (Sadeh & Zion, 2009). Additionally, IBL is a more effective method of correcting misconceptions and clarifying educational material for students in comparison to traditional lecture instructional methods (Şenyiğit et al., 2021). This is because IBL give students the opportunity to consider a question, create a prediction, and test the prediction, which allows them to realize their misconceptions and create new knowledge (Şenyiğit et al., 2021). Furthermore, when properly implemented and transitioned among the inquiry levels, there is a greater understanding of learning objectives, increased practice skills, and improved attitudes towards the subject material (Anwar, 2020).

Conclusion

Along with other active learning styles, IBL promotes an interactive classroom that offers students an autonomy-supported environment, promotes facilitation of their own learning, increases content knowledge, cultivates relationships, and develops higher order thinking skills. While there were no significant differences among IBL levels, our data supports that students were interested, motivated, and engaged while completing IBL activities. Furthermore, this student interest, motivation, and engagement can be a stepping stone for students to develop a personal interest in content material, seek re-engagement with course material, and foster positive collaborative social experiences.

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Appendix 1

Examples of worksheets provided to students

Traditional Case Scenario

Sunshine Dairy, located in Huron County, milks 330 Holstein cows. Last week two cows (791 and 985) calved and this week they are experiencing reduced milk production during the morning milkings. Additionally, the cows have reduced feed intake, are lethargic, and their udders are red and swollen.

The management team is concerned and contacted their local veterinarian to schedule an examination, but the veterinary team is unavailable until tomorrow. The team collected urine samples and milk samples from the left rear udders of both cows. Working as a consulting team, what should you do to diagnose the problem?

Question: What is a potential diagnosis for the cattle?

Procedure: Using the case scenario above and the background information, propose a diagnosis for the cattle that can be tested using the resources at your table. List the hypothesis below.

- Hypothesis:

Procedure continued: Using the instructions found above, run the following tests in the chart below and record the results. Once finished completing each of the five tests, ask your TA to share the predicted results.

	Cow 791	Cow 985
CMT		
Ketostix		
Keto-Test		
Off Flavor Milk		
pH Test		

Procedure continued: Using that information gathered from the test above, create a diagnosis for the two cows. Afterwards, ask your TA to share the predicted conclusion.

- Diagnosis:

Structured Case Scenario

Sunshine Dairy, located in Huron County, milks 330 Holstein cows. Last week two cows (791 and 985) calved and this week they are experiencing reduced milk production during the morning milkings. Additionally, the cows have reduced feed intake, are lethargic, and their udders are red and swollen.

The management team is concerned and contacted their local veterinarian to schedule an examination, but the veterinary team is unavailable until tomorrow. The team collected urine samples and milk samples from the left rear udders of both cows. Working as a consulting team, what should you do to diagnose the problem?

Question: What is a potential diagnosis for the cattle?

Procedure: Using the case scenario above and the background information, create a diagnosis for the cattle that can be tested using the resources at your table. List the hypothesis below.

- Hypothesis:

Procedure continued: Using the instructions found above, run the following tests in the chart below and record the results.

	Cow 791	Cow 985
CMT		
Ketostix		
Keto-Test		
Off Flavor Milk		
pH Test		

Procedure continued: Using that information gathered from the test above, create a diagnosis for the two cows.

- Diagnosis:

Guided Case Scenario

Sunshine Dairy, located in Huron County, milks 330 Holstein cows. Last week two cows (791 and 985) calved and this week they are experiencing reduced milk production during the morning milkings. Additionally, the cows have reduced feed intake, are lethargic, and their udders are red and swollen.

The management team is concerned and contacted their local veterinarian to schedule an examination, but the veterinary team is unavailable until tomorrow. The team collected urine samples and milk samples from the left rear udders of both cows. Working as a consulting team, what should you do to diagnose the problem?

Using the case scenario and background information provided, create an experimental question, hypothesis, procedure, and form a diagnosis.

- Question:

- Hypothesis:

List observations and results below from your diagnostic tests. To run your diagnostic tests, ask your TA for the necessary testing materials.. *Note there is not a required number of diagnostic tests*

Diagnosis: