Assessment of experiential learning in online introductory physics labs during COVID-19

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Assessment of experiential learning in online introductory physics labs during COVID-19

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Abstract

The sudden COVID lockdown has been a challenge for community college faculty in terms of preparation time, restricted mobility and limited resources. On the one hand, the standard face-to-face lab learning outcomes that are used to assess a student’s understanding of the uncertainty, the difference between a “y = ax” versus “y = ax + b” data model, the use of graphical intercept to show systematic error, etc. can be adapted to an online setting when given adequate preparation time. On the other hand, the essence of online lab teaching must include the delivery of some level of experiential activity for which there is convincing evidence in the literature on pedagogy of its worthwhile application. Asynchronous delivery of experiential learning could be used for the synchronous delivery of that learning while the reverse application would require major design changes. Numerous lab videos have been posted on YouTube that were created in the pre-lockdown era and the level of experiential learning in terms of “doing a lab” can be evaluated by replacing the tactile measurement performed in a real lab with an audiovisual measurement shown in a video of a real or simulated instrument in operation. Learning experiences involving simulations would broaden lateral thinking. The “real life doing a lab” transference to “remotely doing a lab” would not be easy to assess during lockdown, when face-to-face practical final exams are impracticable to schedule. Assessment would certainly include grading but grading alone would not provide an adequate holistic assessment. The construction of an assessment rubric for the online experiential learning, based on the McGill University face-to-face experiential learning assessment principle concerning content-process mixture, big picture perspective and reflection is presented here. The advances in artificial intelligence software as it pertains to online experiential learning are discussed.

Keywords

Asynchronous online delivery, experiential learning, tacit and explicit knowledge

Introduction

The online delivery of experiential learning in physics lab classes in Queensborough Community City during COVID-19 has been a challenge in terms of preparation time, restricted mobility, and limited resources. Although ABET in a July 21 2020 Response to the COVID-19 pandemic stated that “It is not necessary to report any short term (current, summer or fall semester) changes to program delivery, content or grading methods to us” [1], it is important for instructors to keep the academic standards as much as possible in the use of remote learning. The Princeton Review Editor-in-chief Franek advice to high school graduates said that “You can think of experiential learning as "learning by doing," but that’s just half of it” [2]. The other half includes
(1) the discovery of what you like, (2) the taking of risk, and (3) learning how to talk about your skills. Specifically, the taking of risk involves a gained experience from success, failure, adventure, and uncertainty.

The National Academy of Engineering 2000 Founders Award Acceptance Remarks by Charles H. Townes described the relationship between science and engineering. Townes emphasized that the relationship is bidirectional [3]. The standard view of science supplying the principles of how things work and that engineering applying these principles to some practical uses is too simplistic. Townes asserted that “It’s true that engineering is much dependent on scientific discoveries and principles. But science is also much dependent on engineering developments. If one is to thrive and grow, then so must the other.”

Creative problem-solving skill is a paramount element for a student to development. The basic mechanism in terms of the interaction between the explicit knowledge and tacit/implicit knowledge has been accepted [4]. Explicit knowledge is readily transmittable in terms of storage media. The application of tacit knowledge in Matsushita Electric Company has been illustrated [5].

Our introductory physics course for engineering students covers mechanics in the first semester and vibration, sound, electromagnetism, etc. in the second semester. The asynchronous delivery of experiential learning in a community college could start at the level of Princeton Review for high school graduates, with an objective of reaching an understanding of the bidirectional relationship between physics and engineering. The goal of helping students to develop creative problem-skill should be preserved as much possible in asynchronous delivery.

Intent and goal

The present expository paper intends to share a set of assessment rubrics for online labs, based on the accepted practice on experiential learning assessment. The goal is to explain our method of transference from face-to-face lab to remote lab, while maintaining the assessment criteria developed prior to the COVID-19 lockdown.

Implementation

The standard face-to-face lab learning outcomes in the understanding of uncertainty can be assessed when the effect of an assumption would include uncertainty. An assumption such as a pulley with negligible mass in a \( F = ma \) lab, a spring with negligible mass in an oscillation lab, an evenly leveled floor in an incline-plane g-measurement lab, or an automatic null setting in a weighing procedure would carry uncertainty. The showing of such uncertainty can be adapted to an online setting when given preparation time. More advanced uncertainty estimation such as the data fitting model difference between “\( y = ax \)” versus “\( y = ax + b \)” in a friction lab, the graphical intercept caused by systematic error in an energy conversion lab, etc. can be delivered asynchronously as well. The sudden switch to online teaching in March 2020 under the COVID-19 lockdown was unexpected. There was little time and resources in a community college to
prepare materials for online delivery, let alone searching for the best pedagogy on showing versus telling, constructing assessment rubrics for asynchronously delivered labs, etc. The 2020 summer months offered some opportunities for reflection and improvement.

The essence of online lab must include the delivery of some level of experiential experience with justification from the literature on pedagogy. Asynchronously delivery of experiential experience could be used for synchronously delivery while the reverse would require paradigm shift to support design changes. Simon Fraser University posts a definition of experiential learning [6]. It states "The strategic, active engagement of students in opportunities to learn through doing, and reflection on those activities, which empowers them to apply their theoretical knowledge to practical endeavors in a multitude of settings inside and outside of the classroom"

There are many lab videos in Youtube. The videos were created in the pre-lockdown era with professional video production crews. Using the Youtube videos, the level of experiential learning in terms of “remotely doing a lab” can be evaluated by replacing a tactile measurement with an audiovisual-only measurement on a real or simulated image of the instrument in operation. For example, the reading of a micrometer setting on an image on Youtube can demonstrate the principle, but without the tactile experience [7]. Asking students to do a simulation exercise on a virtual micrometer would also broaden the micrometer reading experience [8]. Incidentally, the working mechanism of a micrometer has been posted by Instructables, originated from the Squid Lab of MIT Media Lab. The Instructables micrometer repair webpage [9], explained that “In use, the spindle is advanced until the measuring faces contact the feature to be measured, and the graduations on the barrel and graduations on the thimble are combined to produce the measure. ….. The spindle has a thread pitch of 40TPI, meaning that the screw will advance 1/40" for each revolution, and each revolution represents 25/1000". There are 25 uniformly spaced marks around the circumference of the thimble that allow measurements to be read to 1/1000"

The University of Waterloo posted a learning cycle table to illustrate the Kolb’s assertion that knowledge can be created through the transformation of experience [10]. An adaptation example for the case of micrometer remote learning is shown in Table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner has concrete experience</td>
<td>Youtube video shows concrete steps in a micrometer reading</td>
</tr>
<tr>
<td>Learner observes and reflects and acquires a skill</td>
<td>Youtube video provides readings from easy case to difficult case, Virtual micrometer simulation exercises provide practice</td>
</tr>
<tr>
<td>Learner synthesizes with abstract conceptualization</td>
<td>Would a larger diameter thimble give better resolution? How about a larger spindle threads per inch number?</td>
</tr>
<tr>
<td>Learner applies the conceptualization which will used to guide new experimentation for new purposeful experiences.</td>
<td>How could “a large change of something produces a small effect” be used to measure/control a tiny quantity? (laser mirror adjustment screws, mechanical probe of a atomic force microscope)</td>
</tr>
</tbody>
</table>
The tactile experience of turning a micrometer thimble to optimally touch the two surfaces of an object would be difficult to deliver through remote learning without a sizeable budget. Nevertheless, the Kolb’s 4-stage experiential learning cycle could still be offered online at college level. In general, the experiential learning of simulation experience would broaden lateral thinking with several scenarios. For instance, the Colorado University Physics Education Technology PhET simulation exercise on simple harmonic motion SHM has been used as part of a remotely delivered lab [11]; with a supplemental presentation of a non-SHM crankshaft animated oscillation from Penn State University [12]. The linear approximation of a crankshaft as SHM was emphasized in our remote SHM lab, an example of lateral thinking. The corresponding Kolb’s 4-stage experiential learning of SHM is shown in Table 2.

Table 2: Kolb’s 4-stage experiential learning of SHM

<table>
<thead>
<tr>
<th>Stage</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner has concrete experience</td>
<td>PhET simulation shows the cause and effect of SHM with a spring and added masses (M)</td>
</tr>
<tr>
<td>Learner observes and reflects and acquires a skill in data analysis</td>
<td>The data fit of y = ax + b would have an intercept corresponding to the spring mass (m)</td>
</tr>
<tr>
<td>Learner synthesizes with abstract conceptualization</td>
<td>Would a correction due to the spring mass give a better result in the verification of the period formula? How to use calculus to find the effective mass in the period formula as (M + m/3)?</td>
</tr>
<tr>
<td>Learner applies the conceptualization which will used to guide new experimentation for new purposeful experiences.</td>
<td>Under what condition can a non-SHM oscillation of a crankshaft be modeled as SHM</td>
</tr>
</tbody>
</table>

Given that theory and experiment form a universal pair of two orthogonal concepts, the Simon Fraser University description of experiential learning in terms of the application of theoretical knowledge would imply that every lab knowledge will become experimental knowledge. Under the COVID-19 lockdown, the tactile hands-on exercises only have contacts with the keyboards. Such keyboard-only exercises could very well be rejected as hands-on exercises from the lab perspective in a regular semester. The remote lab implementation needs to find some justification in the literature to support the delivery of hands-on experience. Another knowledge pair would be implicit knowledge and explicit knowledge. Explicit knowledge is simply what can be written and shared. Compute system would treat explicit knowledge as those that can be codified. Then the rest of the knowledge would be implicit or tacit knowledge. The reflection process could make tacit knowledge explicit through a questioning process and could reinforce
the development of tacit knowledge [13]. Recently, tacit knowledge measurement has been advocated as an additional academic performance indicator [14].

The “real-life doing a lab” transference to “remotely doing a lab” would not be easy to assess, during lockdown condition in ZZZ City when face-to-face final practical exams are excluded. The acceptance of the use of a metacognition approach is a possibility, even though the assessment effectiveness of “Think about your own thinking” is still an open question.

Assessment Designs

Assessment certainly includes grading but grading alone would not be adequate for a holistic assessment. The Kolb’s learning cycle examples in Table 1 and Table 2 can be used as deliverables for assessment, shown in Table 3 and Table 4. Furthermore, a construction of an assessment rubric for online experiential learning, based on the McGill University face-to-face experiential learning assessment principle in content-process mixture, big picture perspective, and reflection, is presented in Table 5 [15].

Table 3: Assessment rubric example with Kolb’s examples as deliverables in micrometer lab

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Highly competent</th>
<th>Competent</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write concrete steps in a micrometer reading</td>
<td>Clear writing of the concrete steps illustrated in the Youtube video</td>
<td>Contained one mistake.</td>
<td>Contained two or more mistakes.</td>
</tr>
<tr>
<td>Write about the diameter thimble in terms of visualization</td>
<td>Clear writing explaining the visual clarify dependence on the thimble diameter</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Write about the spindle threads per inch (TPI) number effect on resolution</td>
<td>Clear writing explaining the resolution dependence on the TPI number, with a calculation</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Write about TPI number application in 3 other situations</td>
<td>Provided three correct applications</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
</tbody>
</table>
Table 4: Assessment rubric example with Kolb’s examples as deliverables in SHM lab

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Highly competent</th>
<th>Competent</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe the cause and effect in SHM simulation with a spring and added masses (M)</td>
<td>Clear description of the simulation, with numeric information (M) and spring constant.</td>
<td>Contained one mistake.</td>
<td>Contained two or more mistakes.</td>
</tr>
<tr>
<td>Provided data fit of $y = ax + b$ to the period-mass simulation data</td>
<td>Clear description of the meaning of the intercept with the value related to spring mass (m) by a factor less than one</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Made correction due to the spring mass</td>
<td>Provided the justification of using $1/3$ correction factor to the spring mass</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Write about SHM linear approximation in non-SHM oscillation, with 3 examples</td>
<td>Provided three correct examples showing the linear approximation in terms of calculus steps</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
</tbody>
</table>

Table 5: Assessment rubric example for experiential learning of simple harmonic motion

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Highly competent</th>
<th>Competent</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content theory (25%)</td>
<td>Provided clear writing of the SHM theory in own words</td>
<td>Contained one mistake.</td>
<td>Contained two or more mistakes.</td>
</tr>
<tr>
<td>Process activity (25%)</td>
<td>Completed lab simulation with correct data analysis</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Big picture real world perspective (25%)</td>
<td>Gave 2 examples of mechanical SHM in student’s daily life</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
<tr>
<td>Reflection transferrable knowledge (25%)</td>
<td>Provided correct approximation for SHM modeling of a daily life non-SHM oscillation</td>
<td>Contained one mistake</td>
<td>Contained two or more mistakes</td>
</tr>
</tbody>
</table>
Discussion

The explanation of our method of transference from face-to-face lab to remote lab, while maintaining the assessment criteria developed prior to the COVID-19 lockdown is presented. The tentative Table 4 and Table 5 assessment data on the simple harmonic motion lab included three students achieving high competent level, with one resubmission after responding to the comments of the instructor. Seven students were at competent level, with one resubmission. The remaining ten students are still in the process of resubmission in the asynchronous delivery mode. Students in other classes, such as asynchronous delivery of astronomy, showed similar response rate. About half of the assessed astronomy students (N = 60) are still in the process of completing the third-week assignment during the writing of the present paper, that is, in the seventh week of Fall 2020. While more data would be collected next semester, it is important to address some remaining open questions.

The assessment of tacit knowledge posts a fundamental question, namely, can tacit knowledge be made explicit? A quantitative assessment would use a rubric to generate scores and repeated training could mimic tacit knowledge improvement. On the one hand, the riding of a bicycle is usually accepted as an example of tacit (or implicit) knowledge. On the other hand, the associated physics equations offer explanation such that a learner could choose to adhere to the physics principles and be trained accordingly. A 2020 report in the use of implicit knowledge by children in a buoyance inquiry experiment showed that about 20 percent of the studied children were able to understand the mass and volume dual variables without the advanced verbal skill of articulation, while some children focused on the mass only and some children focused on the volume only [16]. A basketball projectile depends on the speed and direction and a novice player can focus one either speed or direction. An expert player can control speed and angle simultaneously. There are at least two “Expert” handbooks on the market as far as we know, namely, the “2018 Cambridge Handbook of Expertise and Expert Performance” [17] and “2019 Oxford Handbook of Expertise” [18], for those interested in learning more about being an expert.

On the one hand, when implicit knowledge is modeled as an ability, latent variable modeling has been shown to be useful for quantitative description [19]. Our previous ASEE Mid Atlantic Fall 2017 Proceedings paper on latent variable modeling using LISREL software can be applied for further analysis of the rubric scores [20]. On the other hand, a tacit to explicit knowledge conversion method using visualization without linguistic and algebraic means has been proposed [21]. A novice basketball player wishing to improve performance could use the vector diagram sketches to understand projectile motion, without the detailed graphical solution learned in physics lessons. A recent PNAS report concluded that while the studied honeybees acquired “implicit knowledge about the statistical properties of the visual environment” just like human, the advanced encoding scheme in human enables better probabilistic computational faculties [22]. Soon enough, a statistical learning AI system having improved encoding would be able to include diagrams/sketches and classify some tacit knowledge as explicit knowledge for straight forward pedagogy assessment without latent variable modeling. In terms of social learning, the learning of a second language with implicit/tacit knowledge is well documented [23]. The story telling of mishaps in engineering laboratories for enticing novices into doing research projects through tacit knowledge communication is another example of social learning [24]. There is no doubt that AI software applications are extending into affective learning and quantifying implicit knowledge in social learning.
Conclusions

The present paper described an asynchronous online delivery of remote introductory physics labs in a community college during the COVID19 lockdown in New York City. The implementation of experiential learning benefited from the literature on pedagogy and assessment rubric examples developed prior to the COVID19 lockdown. The tacit/implicit knowledge conversion to explicit knowledge was presented.

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