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ARTICLE
Lt: A Resource to Future-Proof the Laboratory in Uncertain Times

Brandon Calderon[1], Charlotte Steel[1], Bridget Ford[2], Jacqui Sue[1] and Katie Bracewell[1]
[1]ADInstruments, Dunedin, New Zealand, 9016; [2]Department of Biology, University of the Incarnate Word, San Antonio, Texas, 78209.
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The COVID-19 pandemic abruptly challenged educators to transition previously in-person courses to an online environment. This has been especially difficult for laboratory courses where students must experience the process of science to develop lab skills and scientific competencies. Due to the uncertainty caused by the pandemic, it is essential that instructional resources are flexible and robust for use in various potential learning environments. The Lt software platform (ADInstruments) is a resource designed to support in-person, online, and hybrid learning environments. Lt supports the in-person lab experience by integrating with data collection hardware and facilitating collaboration through group-based activity. In addition, the platform also provides several avenues for teaching online labs using the same experiments that would be done on campus. At home, students can analyze Lt's built-in example data, or be supplied with low-cost hardware to complete labs remotely. In conjunction with other online tools, Lt can support online group work and student collaboration. Lt hosts a wide range of pre-built lab experiments and activities covering neuroscience, anatomy, physiology, clinical health science, biology, and chemistry. Although the material can be used "out-of-the-box", the content is completely editable and new labs can be created. Feedback from students suggests that Lt has proved valuable for supporting flexible instructional practices during the pandemic.

Key words: Lt; ADInstruments; laboratory experiments; remote learning; hybrid learning; blended learning; hands-on experiments; online content delivery; student engagement; distance learning; online learning

The magnitude of disruption to education caused by the COVID-19 pandemic was unprecedented. Throughout the pandemic many schools in the US and Canada remained in a partially-closed state, canceling in-person classes for the safer alternative of online instruction. It is likely no surprise to the readers of JUNE that the COVID-19 pandemic contributed to heightened anxiety felt by many (American Psychiatric Association, 2020). Yet, there is growing hope. Increased manufacture and distribution of multiple COVID-19 vaccines, combined with public adoption, should eventually help us get back to some sense of normalcy. Many colleges and universities planned to return to a form of in-person instruction by Fall 2021 (Burke, 2021). However, given the flexibility provided by online teaching, and the lingering effects of the pandemic, the amount of technology used to teach is unlikely to return to pre-pandemic levels.

THE CHALLENGE OF CHANGING INSTRUCTION

The COVID-19 pandemic forced educators to adapt to new methods of instruction in a short period of time while often lacking proper resources and support (Ao, 2020; Petzold, 2020; Colthorpe and Ainscough, 2021). Uncertainty surrounding when the COVID-19 pandemic will truly be over further challenges educators to be prepared to teach across multiple potential learning environments. Moving forward, institutions should ensure educators are supported by flexible instructional resources. These resources should accommodate in-person and online instruction, while minimizing educator stress and detrimental effects on student outcomes and engagement.

A FLEXIBLE RESOURCE FOR LABS

One such resource offered to educators is the blended-learning software platform, Lt (ADInstruments; Appendix: Item #1). Lt was originally built for in-person life science lab environments, providing interactive online content, authentic data acquisition with integrated hardware, and data analysis tools. An added benefit of Lt, however, is its adaptability. Most pre-built lab experiments in Lt include example data (Figure 1). Example data were initially included as a back-up for analysis when students may have collected poor data or had to make up a missed lab. Example data became even more valuable assets during the COVID-19 pandemic, as educators were able to continue teaching students the results of hands-on experiments remotely - even if they could not be in the lab. While in-person laboratories are thought to promote physical skills, troubleshooting abilities, and exposure to authentic data collection, including the need for time management (as reviewed by de Jong et al., 2013), example data still allow students to gain experience in data analysis, and can be accompanied by assessment questions. In a survey of international physiology educators, most indicated that they used example data in their labs during the COVID-19 pandemic to promote data interpretation skills (Choate, 2021).

Another option available to educators was to use LabChart Reader, another ADInstruments product, with example data (Appendix 1: Item #2). This is free, compared to the subscription-based Lt platform. While LabChart Reader allows students to view and manipulate data, Lt

Figure 1. The Lt software platform displaying example data for the “Diving Response” lab.

does this while also providing pre-built lessons, assessment questions, grading functionality, and integration with learning management systems.

VISION

Lt was built on the vision of Dr. Tony Macknight, a Fellow of the Royal Society of New Zealand and previously the Wolf Harris Professor of Physiology at the University of Otago, Dunedin, New Zealand (Macknight, 2017). Dr. Macknight has a keen interest in education and promoted problem-based learning for medical students studying physiology at the University of Otago (Macknight, 2017). As a result of this vision, Lt permits educators to build content from scratch using simple authoring tools, or download pre-built, fully-editable lab content and experiments. Lt hosts an extensive range of interactive panels, including text boxes, questions (including multiple choice, Drag and Drop, Categories, and Image Annotation), data collection and analysis, and multimedia such as images, video, and audio (Figure 2). Furthermore, Lt permits educators to modify any lesson or lab developed by ADInstruments and its partners (Appendix 1: Items #3-4).

Due to pandemic disruptions, globally, educators have been required to transition their on-campus lab courses to an online format. Prior to the pandemic, many educators used the pre-built labs in Lt as-is, but often chose to modify the content over time as they became familiar with Lt’s capabilities. In response to the pandemic, educators at the University of Tasmania modified anatomy and physiology units for a first-year course (Appendix 1: Item #5). Prior to the pandemic, students attended 2-hour practical sessions in a laboratory space on campus each week, with most physiology laboratories using Lt and PowerLab (Appendix 1: Item #6) technology.

When COVID-19 affected the ability to teach on campus, all practicals at the University of Tasmania were shifted online and became asynchronous to promote flexibility for students. While the physiology laboratories were already established on the Lt platform, they were adapted for a remote learning context via the addition of videos and contextual information regarding what would be happening in the physical lab. Educators used a mix of their own data and data supplied by ADInstruments. To address the anatomy component, the educators ported their own anatomy content into Lt and made use of the interactive features of the platform, like labelling questions. Students appreciated that the labs were flexible but did struggle with remote, self-directed learning.

Similarly, in response to the pandemic, educators at the University of Sydney were required to engage in emergency remote teaching to deliver their second-year medical science course online (Appendix 1: Item #7). Prior to the pandemic, Lt was used in the course laboratories, where students collected data, as well as in tutorials, data workshops, and team-based learning sessions. When educators needed to pivot to an online learning format, they created and added videos to the existing labs, as well as additional instructions, images, and questions. The data from the previous year’s class were used, enabling the analysis of authentic data. The online labs were presented synchronously in combination with Zoom (Zoom Video Communications, Inc.; Appendix 1: Item #8), and educators kept track of students’ progress using the data analytics tool in Lt. To gauge the lessons’ reception, the educators also created and incorporated a lesson evaluation at the end of each lab in Lt.

THE NEUROSCIENCE COLLECTION

The Neuroscience Collection in Lt contains interactive labs that require students to participate in active learning by

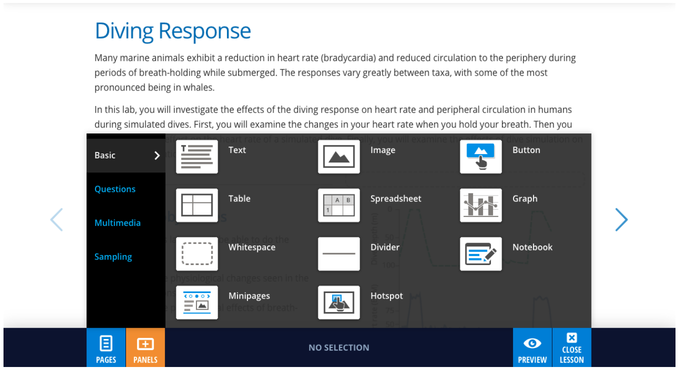

Figure 2. The Lt software platform offers a range of tools that can be used to edit preexisting content or to add your own content to the platform.

Labs Available in the Lt Neuroscience Collection

1. Autonomic Nervous System
2. Biofeedback
3. Brain Structure and Reflexes
4. Cockroach Sensory Nerve
5. Cockroach Ventral Nerve Cord
6. Diving Response
7. Earthworm Action Potentials
8. EDR and Classical Conditioning
9. Electrodermal Response (EDR)
10. Electroencephalography (EEG)
11. Electrooculography (EOG)
12. Frog Nerve
13. Frog Neuromuscular Junction
14. Intracellular Action Potentials
15. Muscle and EMG
16. Peripheral Nerve Function
17. Reflexes and Reaction Times
18. Sensory Illusions
19. Sensory Physiology
20. Size-Weight Illusion
21. Skeletal Muscle Function
22. Stroop Test
23. Visual Evoked Potentials (VEP)

Table 1. List of labs available in the Lt Neuroscience content collection. More information on the collection can be found at https://www.adinstruments.com/lt/neuroscience.

collecting and analyzing their own data. Lab activities are structured around a set of learning objectives, and videos and step-by-step instructions help guide students through lab protocols. Students engage with the content by answering interactive questions, helping to bridge the gap between data analysis and key neuroscience concepts learned in class.

The Neuroscience Collection consists of 23 interactive laboratories and 23 pre-lab prep lessons (PLPs). The PLPs provide background material and a brief quiz to ensure students understand key concepts required to successfully complete the associated lab. As students progress to the labs, they are guided toward a deeper understanding of the nervous system and the brain, with a focus on neurophysiology and the supporting anatomy. Students who use the collection are exposed to a mixture of human and animal experiments, including activities focused on cockroaches, earthworms, and frogs. Students are also introduced to psychophysiology studies, including the electrodermal response, classical conditioning, sensory illusions, Stroop test, and size-weight illusion (Table 1).

In addition to the Neuroscience Collection, the Anatomy Collection contains multiple labs with a neuroscience focus, including a brain dissection lab, a nervous system model lab, a special senses histology lab, and a special senses model lab.

The "Reflexes and Reaction Times" lab in the Neuroscience Collection involves students testing common reflexes and reaction times with a volunteer. By the end of the lab, students are expected to be able to elicit a knee-jerk reflex, a consensual pupillary reflex, and an example of a withdrawal reflex. They are also expected to be able to explain a knee-jerk reflex, the pathways in a withdrawal reflex, and to examine factors which alter reaction times. These learning objectives ensure that students are alerted to the salient information within the lab.

Before beginning the "Reflexes and Reaction Times" lab, instructors can provide students with the associated PLP, which contains a list of questions designed to test students' understanding and knowledge (for example, "What is one defining property of a voluntary action that differentiates it from a reflex?"). In both the PLP and the lab itself, the 'Background' page presents fundamental information that students should know. In this lab, this page defines reflexes, then discusses reflex arcs (mono- and polysynaptic), the stretch reflex, the flexion withdrawal reflex, and the pupillary light reflex. Before setting up the experiment and completing the activities, students are asked to complete a 'Challenge' page, which tests students on key concepts, like the components of a reflex arc (Figure 3). As seen in Figure 3, the labs are supplemented with a variety of illustrations.

Each lab in Lt revolves around a core activity (or activities) and the analysis of the resulting data. For example, the knee-jerk reflex activity in this lab requires students to set up the tendon hammer, electrodes, and PowerLab (ADInstruments; Appendix 1: Item #6). They are guided through this process with simple instructions, supplemented by images and video. Data analysis is similarly scaffolded, and students can use inbuilt tools to manipulate their data. In the "Reflexes and Reaction Times" lab, students use the 'Marker' and 'point selector' tools to determine the latency and amplitude of the knee-jerk reflex under normal conditions and when performing the Jendrassik maneuver (Figure 4). They are also asked to use the 'region selector' tool to determine the latency of reaction times in response to visual and auditory cues, as well as the effects of forewarning, predictable stimulus frequency, and distraction. Finally, students are asked to compare the latency of a reflex to that of a voluntary contraction.

After analyzing their raw data, students are asked to complete 'Check your understanding' questions. These questions require students to interpret their data (for example, "What does the effect of the Jendrassik maneuver indicate about the neural pathways involved in simple reflexes?"), and can be set as graded or ungraded, depending on whether summative or formative assessment is desired.

Educators check student progress and performance by

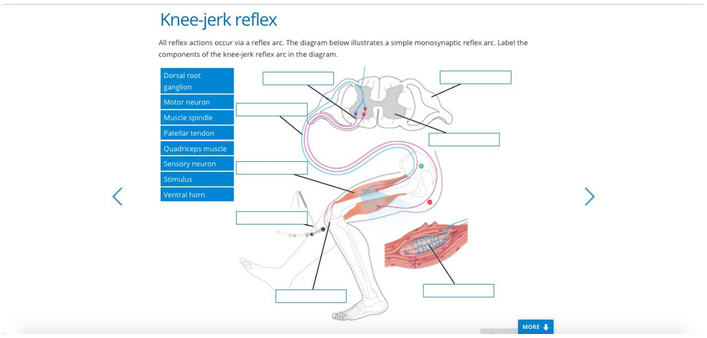

Figure 3. The 'Challenge' page in the "Reflexes and Reaction Times" lab in Lt asks students to label the components of the knee-jerk reflex arc before they test this reflex with a volunteer.

using the analytics and grading tools in Lt (Figure 5), and and students can create a personal record via downloadable PDF lab reports.

The Neuroscience Collection is compatible with the research-grade PowerLab data-acquisition system or USB-connected Lt Sensors (Appendix 1: Item #9). These instruments allow students to collect data (Figure 6), while the accompanying content and pre-set filtering of collected data in Lt allow students to focus on conceptual understanding rather than the more technical aspects of analog-to-digital data collection and signal filtering. Lt can be used without any sensors at all if only example data are used.

SURVEY INSIGHTS

In the past year, ADI has received a student survey on the use of Lt throughout the COVID-19 pandemic.

STUDENT SURVEY

The following are the results of a student survey provided to ADInstruments by Dr. Bridget Ford from the University of the Incarnate Word, San Antonio, Texas. The students were from the BIOL 2121/Anatomy and Physiology I (n = 93) and BIOL 2122/Anatomy and Physiology II courses (n = 25). Students complete the BIOL2121 course and associated lecture series before enrolling in BIOL2122 and its associated lecture series. Over the course of BIOL2121 (Aug 24-Dec 11 2020), students completed labs in Lt on the following topics: tissue histology (Lab 3); integumentary system (Lab 4); axial skeleton (Lab 5); appendicular skeleton and joint classification (Lab 6); skeletal muscle function (Lab 7); muscles of the anterior and posterior compartments (Lab 8); muscle physiology and EMG (Lab 9); introduction to the nervous system (peripheral and central; Lab 10); cranial nerves (Lab 11); autonomic nervous system (Lab 12); and eye dissection (Lab 13). Where available, PLPs in Lt were also provided to students (Labs 4, 7-12).

During the other course, BIOL2122 (Aug 24-Dec 11 2020), students completed labs in Lt on the following topics: blood characterization and hemostasis (Lab 2); heart anatomy, heart valves, and heart sounds (Lab 3); cardiovascular effects of exercise (Lab 4); blood pressure, flow, and resistance (Lab 5); peripheral circulation (Lab 6); respiratory histology and structures (Lab 8); lung anatomy, airflow, and respiratory mechanics (Lab 9); digestive system (Lab 10); and urinary system and fluid balance (Lab 11). Where available, PLPs in Lt were also provided to students (Labs 2-10).

Survey Prompt	Average Score (1-5)	Mode
What is your overall rating of the Lt Lab Software?	4.2	5 (49.18%)
The Lt pre-lab and lab assignments facilitated my learning.	4.1	5 (46.72%)
The Lt laboratory exercises measured my knowledge of the course material and helped to meaningfully expand on the material taught during lecture.	4.1	5 (38.52%)
The Lt web-based software was user-friendly and easy to navigate.	4.5	5 (66.39%)
The Lt web-based software increased my knowledge and skills in the subject matter.	4.1	5 (45.08%)

Table 2. University of the Incarnate Word Anatomy and Physiology I and II student responses specific to the use of Lt over the Fall 2020 semester (n=118). For the first question, 1 indicates lowest rating and 5 highest rating. For other questions, scores ranged between 1 and 5; '1' indicated 'Strongly Disagree' and '5' indicated 'Strongly Agree'.

The "turnkey" labs supplied by ADInstruments were modified in Lt so that they were more suited to distance learning. These modifications kept the pre-built material largely intact but adjusted the protocols to accommodate the example data being used, while providing students with information about how the data were collected. Dissection videos provided in Lt were used to replace dissection protocols, and point values were added to all questions. The labs were then shared with instructors in Lt. Instructors did not edit the labs and were only responsible for enrolling students into the correct sections and publishing material at set times.

Most of the students enrolled in BIOL2121 were not familiar with biology or physiology before taking the course. The BIOL2121 lab course and associated lectures do not have any prerequisites, as this course can be taken as a core science course for non-majors (pre-nursing, rehabilitative sciences, kinesiology, nuclear medicine). The remaining students are biology or biochemistry majors who take the course after completing General Biology I and II, and these students form a minority that do have laboratory experience. Those students enrolled in 2122 are generally second-semester freshmen or rising sophomores. Many of these students have experienced another science or science-related course.

Students were given a survey using Microsoft Forms (Appendix 1, Item #10). This survey asked students to rate the Lt platform and to evaluate its utility in facilitating learning. They were also asked to rate its ease of navigation and user-friendliness. The average score for all metrics

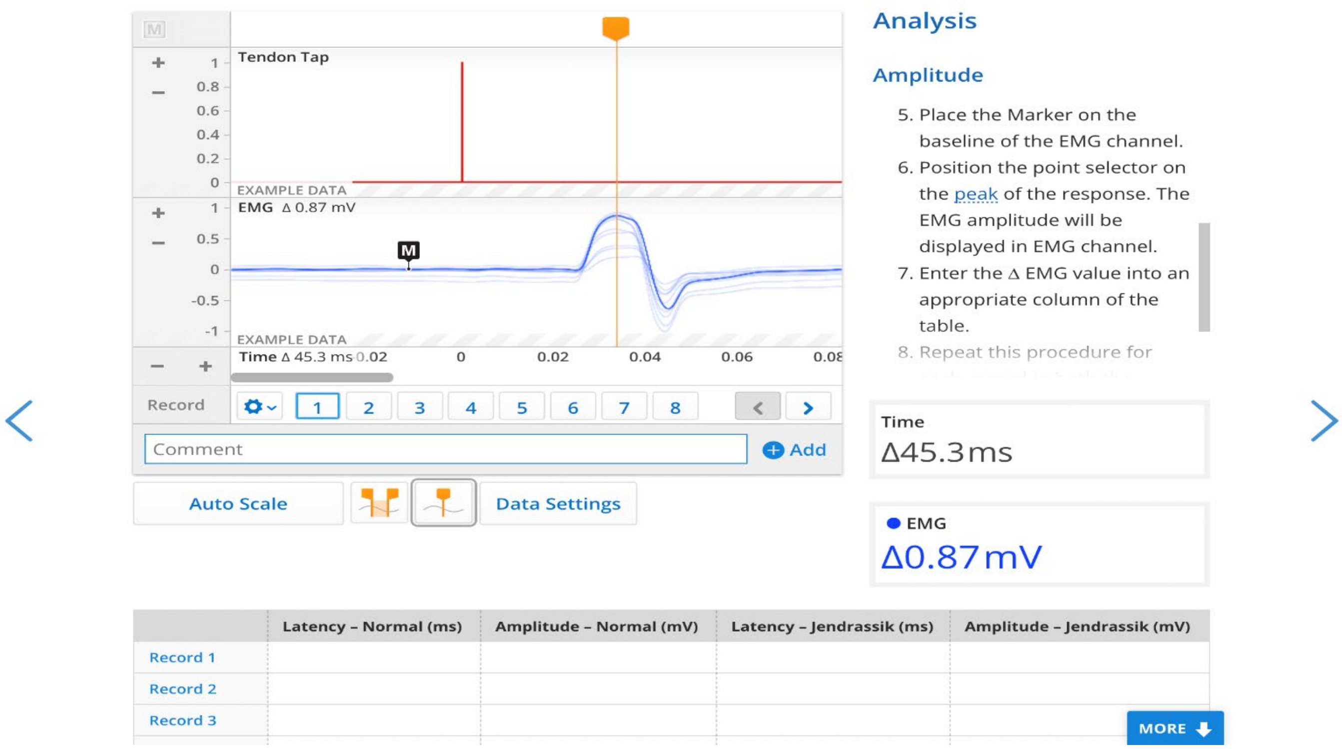

Figure 4. Students can use in-built data analysis tools to determine the latency and amplitude of the knee-jerk reflex in their volunteer.

exceeded 4 (on a 5-point scale; Table 2). Further data related to this survey, showing the breakdown of responses, are provided in the Appendices.

Students provided positive feedback about the range of anatomy and physiology labs in Lt, including those that addressed the brain:

> *"I really liked the lab about the brain/nervous system! It was super interesting learning about how different parts of the brain, when damaged, affected the patient. The nervous system is also one of my favorite topics so that made it fun too"* [A&P I, Anatomy Collection]

> *"My favorite lab activity was the autonomic nervous system, I found it interesting learning about the different nerves."* [A&P I, Neuroscience Collection]

> *"My favorite lab activity was the cranial nerve exam (lab 11) because I was able to complete a "work up" on my sister which made me feel like I was using my knowledge to examine someone."* [A&P I, Anatomy Collection]

While the general consensus was positive, when asked, "What are one to three specific things about the course that could be improved to better support student learning?", students did touch upon the necessity of in-person learning:

> *"Overall I believed this current system was great in terms of learning online, but it would of [sic] been better to have been in class face to face."* [A&P I]

> *"I wish it was [sic] in person I think being hands-on in this type of lab would especially improve student learning, but the online course is set up just fine."* [A&P I]

Evidently, students value the in-lab, hands-on experience that can only be achieved by physically inhabiting a laboratory space. Lt can support in-person and remote learning, and will substitute for hands-on data collection in the lab when remote learning is necessary.

MOVING FORWARD

While some have argued that online instruction for a lab-intensive course can be "close to, and at times better than, in-person teaching" (Vutukuru, 2020), the experience of others suggests that both students and educators have a newfound appreciation for the in-person academic environment, due to the personal connections and increased engagement it fosters compared to being online (Colthorpe and Ainscough, 2021). The ease with which teaching can be transitioned online will also depend significantly on the type of lab course being taught—anatomical dissections cannot be done at home, while electronic material might be easily shipped to students in an engineering course (Vutukuru, 2020). There is little doubt that many educators and students prefer in-person instruction, as partly evidenced by this paper. Ongoing uncertainty caused by the pandemic, however, requires educators to develop adaptable instructional practices that

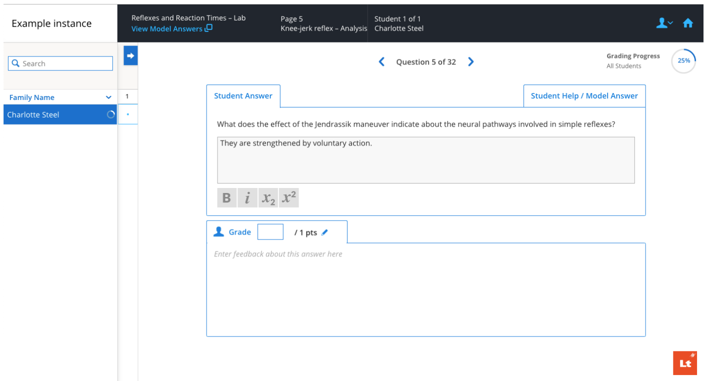

Figure 5. Educators can view the student answer, review the model answer, assign points, and provide feedback to the student.

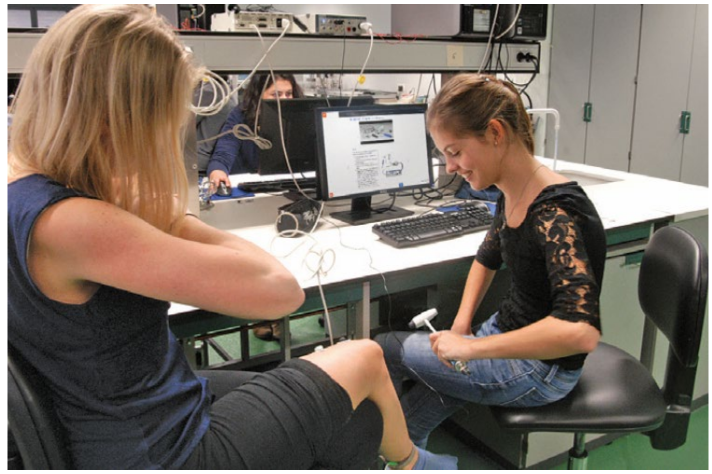

Figure 6. Students working through the "Reflexes and Reaction Times" lab in Lt.

can facilitate an in-person, hybrid, or online learning environment, without sacrificing academic rigor.

While the negative effects of disruption on students and educators cannot be understated, the COVID-19 pandemic has also fostered digital community and peer collaboration between educators. This is evident in many society listservs and the Faculty for Undergraduate Neuroscience's 'Neuro in the time of Corona' resource repository (Appendix 1, Item #12). In one study, 70% of physiology educators (n=10) reported increased "interdisciplinary collaborations and teamwork opportunities, both inside and outside their own institutions" (Choate, 2021). We saw educators quickly develop and share free lesson content utilizing free and commercial online simulation tools (Heitler, 2022; Meir, 2022, this issue; Appendix 1, Items #13-14). We also saw industry freely offer their EdTech tools to immediately assist educators and their students through the toughest parts of the pandemic (Appendix 1, Items #15-17).

Through these efforts, educators gained experience in the application of a variety of EdTech tools. While issues of equity and stress were most likely felt in the rush to online education, educators have indicated a more positive outlook on EdTech tools and the value they offer to education moving forward (Lederman, 2020). Physiology instructors have also indicated that the pandemic offered an opportunity to "rethink" their teaching, and most will continue to incorporate an aspect of online delivery in their labs in the future (Choate, 2021). Being prepared for future disruption is vital to minimizing any negative effects on students and educators should the educational landscape remain volatile.

Perceived issues related to moving physiology lab courses online include reduced engagement and peer and tutor interaction, as well as preventing students from developing physical lab skills and an appreciation of biological variation (Choate, 2021). We suggest that a worthwhile online lab experience can still be achieved. Ideally, an online lab environment will keep students engaged in the process of science while developing cognitive skills and lab competencies (where possible) when in-person learning is not available. Lt attempts to do this through the analysis of example data, alongside assessment questions, images, and video. Reflecting the idea that communication and collaboration are key scientific skills, Lt promotes group work by permitting students to log-in as a group to complete labs together. Educators can continue to use this feature in online learning environments by combining Lt with one of the many online meeting tools available (Appendix 1, Item #18). Altogether, these features and tools enable students to explore and understand the key concepts they would encounter in the lab. Whether in-person, online, or hybrid, Lt ensures that lab courses are prepared for potential disruption.

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Address correspondence to: Charlotte Steel, ADInstruments, 77 Vogel Street, Dunedin, OTA 9010. Email: c.steel@adinstruments.com

APPENDIX 1

LIST OF RESOURCES

(1) Lt. ADInstruments: https://www.adinstruments.com/lt

(2) LabChart Reader. ADInstruments: https://www.adinstruments.com/products/labchart-reader

(3) ADInstruments Partner – Touch of Life Technologies: https://www.toltech.net/

(4) ADInstruments Partner – Vernier: https://www.vernier.com/

(5) Lt Global Brain Trust 2020 Presentations. Day Three: Tracy Douglas. ADInstruments: https://www.adinstruments.com/lt-global-brain-trust-2020-presentations?wchannelid=fui44u1nlu

(6) PowerLab – High performance data acquisition hardware. ADInstruments: https://www.adinstruments.com/products/powerlab-daq-hardware

(7) Lt Global Brain Trust 2020 Presentations. Day Three: Tina Hinton. ADInstruments: https://www.adinstruments.com/lt-global-brain-trust-2020-presentations?wchannelid=fui44u1nlu

(8) Zoom. Zoom Video Communications, Inc: https://zoom.us/

(9) Lt Sensors - A cost effective way for your students to record biosignals directly into Lt via USB. ADInstruments: https://www.adinstruments.com/lt/sensors

(10) Microsoft Forms. Microsoft: https://www.microsoft.com/en-us/microsoft-365/online-surveys-polls-quizzes

(11) Google Forms. Google: https://www.google.com/forms/about/

(12) 'Neuro in the time of Corona' Resource List. Courtesy of the Faculty for Undergraduate Neuroscience and contribution authors. https://docs.google.com/document/d/1ChuOfTnKwAQqIKcaosrmAtygtxGAfb4MS3M6VMth_Uo/edit?usp=sharing

(13) Neuromembrane Simulator. Courtesy of University of Alberta, Drs. Declan Ali, Greg Funk, Kelvin Jones, and Atmist. https://neuromembrane.ualberta.ca/account/login

(14) Neuron Simulation Lab. Courtesy of Dr. Bob Calin-Jageman.

(15) COVID-19 response. ADInstruments: https://www.adinstruments.com/lt/covid19

(16) Remote Learning Solutions for College. Vernier: https://www.vernier.com/remote-learning/college/

(17) COVID-19: Move Your Science Course Online with Labster. Labster: https://www.labster.com/covid-19/highered/

(18) Remote Group Work in Lt. ADInstruments: https://www.adinstruments.com/support/documentation/remote-group-work-lt

APPENDIX 2

Survey 1: Responses regarding Lt from students (n=118) who took Anatomy and Physiology I and II courses at the University of the Incarnate Word over the Fall 2020 semester. For the first question, 1 indicates lowest rating and 5 highest rating. For other questions, scores ranged between 1 and 5; ‘1’ indicated ‘Strongly Disagree’ and ‘5’ indicated ‘Strongly Agree’.

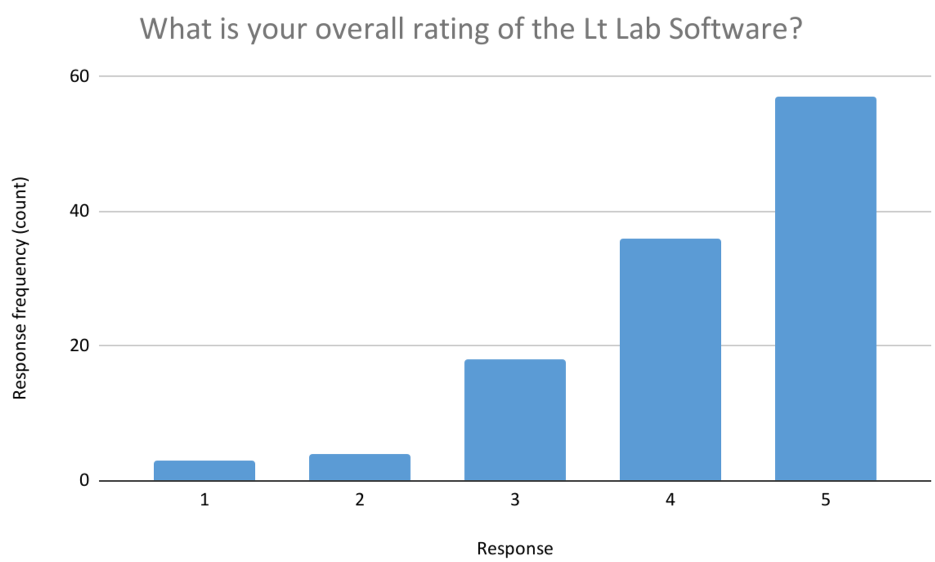

Figure 1. Students (n=118) taking Anatomy and Physiology I and II at the University of the Incarnate Word were asked to rate the Lt software platform, based on their use of the platform during the Fall 2020 semester. 1 indicates lowest rating and 5 highest rating.

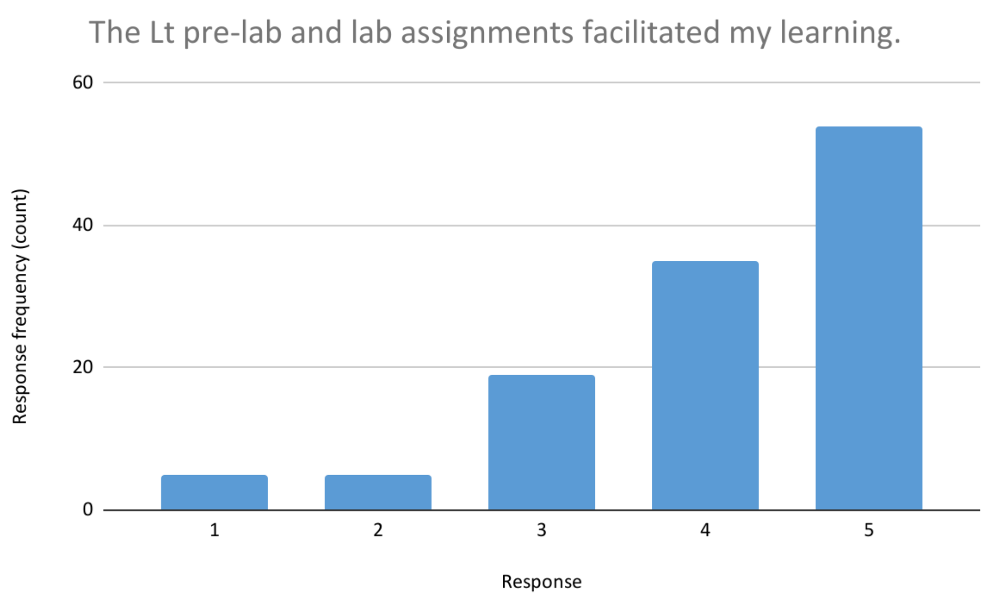

Figure 2. Students (n=118) taking Anatomy and Physiology I and II at the University of the Incarnate Word were asked to rate whether the Lt software platform facilitated their learning, based on their use of the platform during the Fall 2020 semester. Scores ranged between 1 and 5; ‘1’ indicated ‘Strongly Disagree’ and ‘5’ indicated ‘Strongly Agree’.

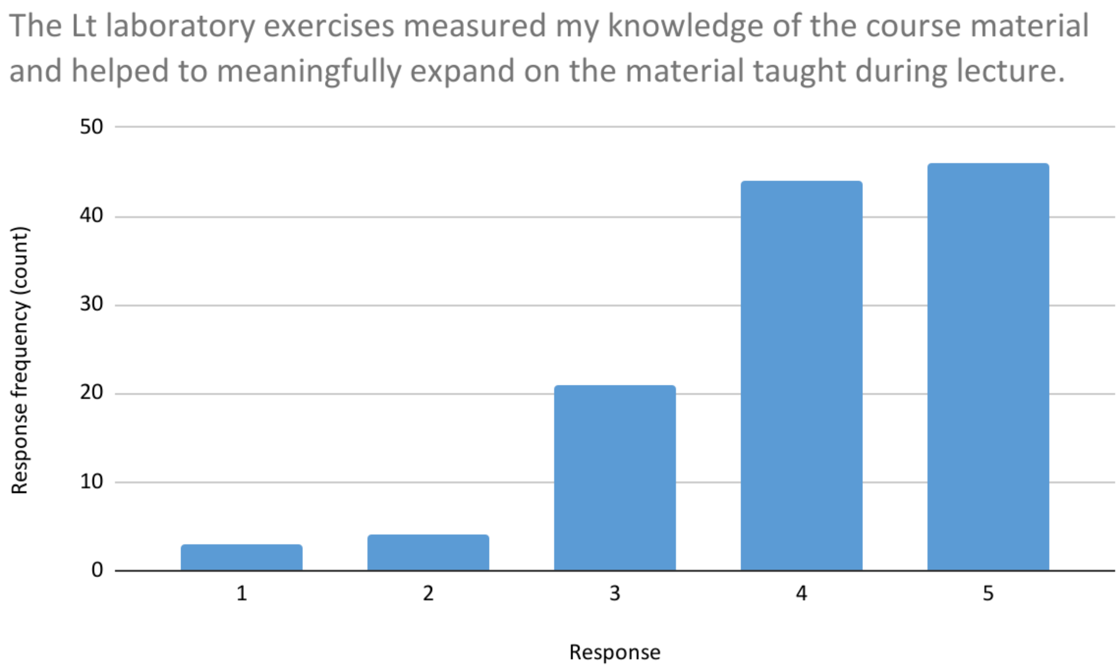

Figure 3. Students (n=118) taking Anatomy and Physiology I and II at the University of the Incarnate Word were asked to rate whether the Lt software platform measured their knowledge of the course material and helped to meaningfully expand on the material taught during the lecture, based on their use of the platform during the Fall 2020 semester. Scores ranged between 1 and 5; '1' indicated 'Strongly Disagree' and '5' indicated 'Strongly Agree'.

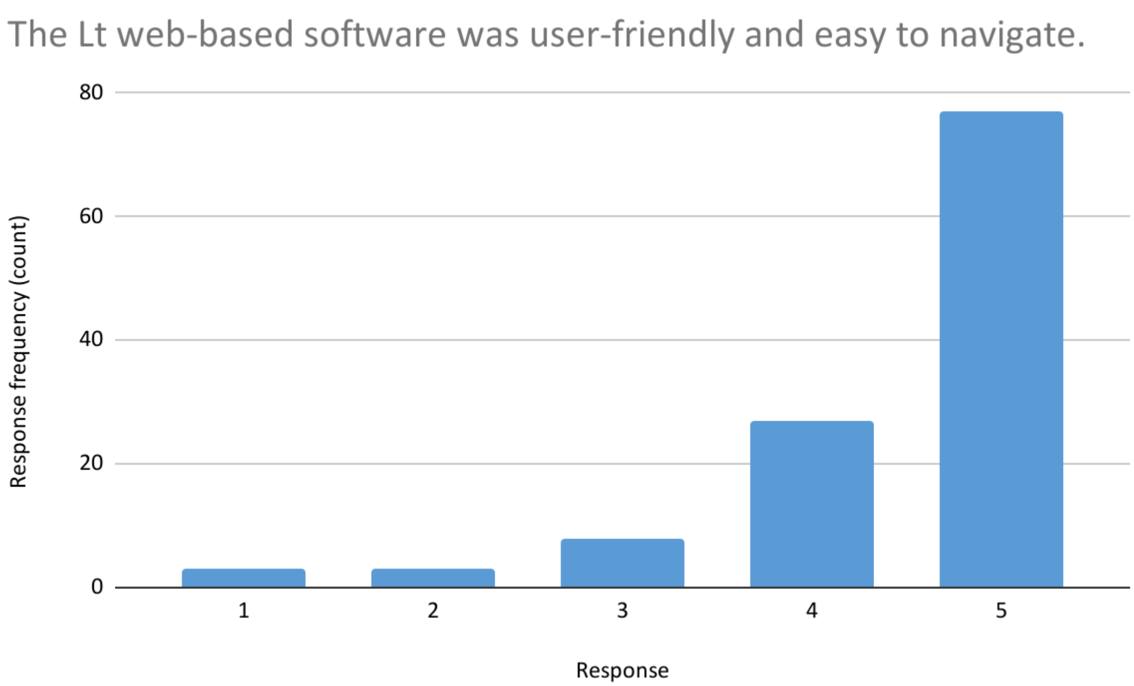

Figure 4. Students (n=118) taking Anatomy and Physiology I and II at the University of the Incarnate Word were asked to rate whether the Lt software platform was user-friendly and easy to navigate, based on their use of the platform during the Fall 2020 semester. Scores ranged between 1 and 5; '1' indicated 'Strongly Disagree' and '5' indicated 'Strongly Agree'.

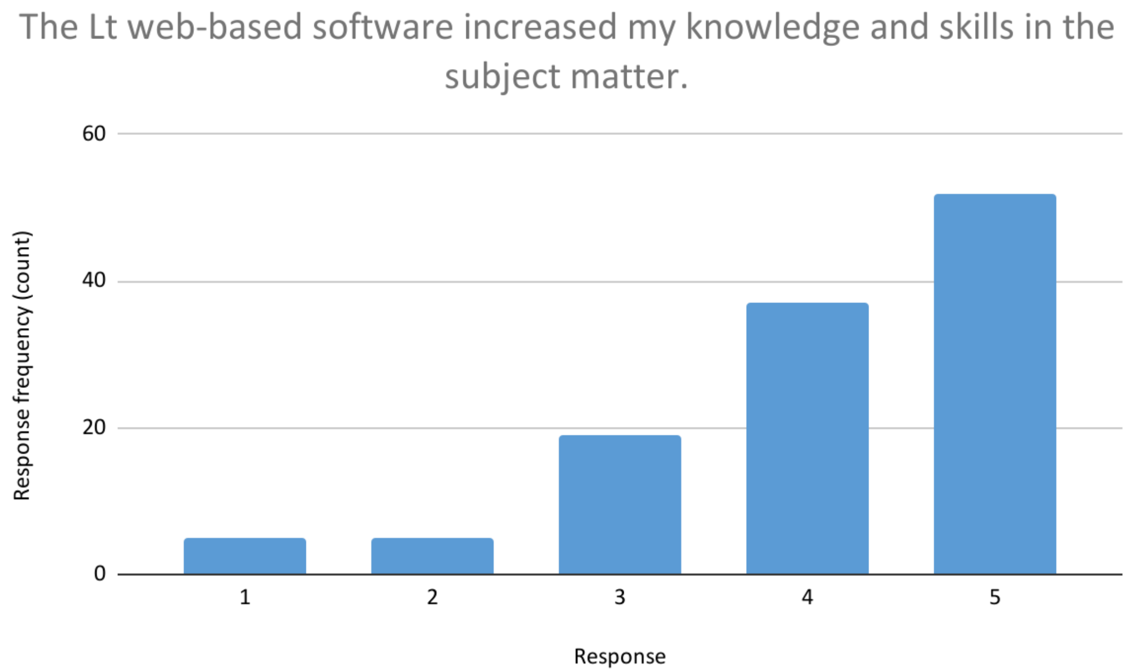

Figure 5. Students (n=118) taking Anatomy and Physiology I and II at the University of the Incarnate Word were asked to rate whether the Lt software platform increased their knowledge and skills in the subject matter, based on their use of the platform during the Fall 2020 semester. Scores ranged between 1 and 5; ‘1’ indicated ‘Strongly Disagree’ and ‘5’ indicated ‘Strongly Agree’.