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Laboratoires virtuels pour les cours de formation générale postsecondaire et de sciences appliquées : perceptions des professeurs

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See table of contents

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Article abstract

General education science courses at a Canadian postsecondary institution implemented Beyond Labz virtual science labs. Faculty members teaching vocational science-related courses tested this resource. This qualitative study explores faculty member and learner perceptions of the efficacy of these virtual labs in terms of ease of use, designing hands-on activities, student engagement, and accessibility. Data are collected via a focus group, surveys, meetings, and interview notes. The study found that learners and faculty members may have different perceptions of the importance of virtual labs for the development of various skills. From the data, five themes emerge related to addressing the needs of diverse learners and utilizing multiple affordances of virtual labs. Although science virtual labs are perceived as a useful tool for teaching and learning science, faculty members identify barriers such as the need to develop digital literacy skills and initial training and institutional support when introducing new tools. Recommendations for effective science virtual labs curriculum integration are included.

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Abstract

General education science courses at a Canadian postsecondary institution implemented *Beyond Labz* virtual science labs. Faculty members teaching vocational science-related courses tested this resource. This qualitative study explores faculty member and learner perceptions of the efficacy of these virtual labs in terms of ease of use, designing hands-on activities, student engagement, and accessibility. Data are collected via a focus group, surveys, meetings, and interview notes. The study found that learners and faculty members may have different perceptions of the importance of virtual labs for the development of various skills. From the data, five themes emerge related to addressing the needs of diverse learners and utilizing multiple affordances of virtual labs. Although science virtual labs are perceived as a useful tool for teaching and learning science, faculty members identify barriers such as the need to develop digital literacy skills and initial training and institutional support when introducing new tools. Recommendations for effective science virtual labs curriculum integration are included.

Keywords: education technology, faculty member professional development, general education, polytechnic institutions, science virtual labs

Résumé

Les cours de sciences en éducation générale dans un établissement postsecondaire canadien ont mis en œuvre les laboratoires scientifiques virtuels Beyond Labz. Les membres du corps enseignant dispensant des cours de sciences à vocation professionnelle ont testé cette ressource. Cette étude qualitative explore les perceptions des membres du corps enseignant et des apprenants sur l'efficacité de ces laboratoires virtuels en termes de facilité d'utilisation, de conception d'activités pratiques, d'engagement des étudiants et d'accessibilité. Les données sont recueillies par l'entremise d'un groupe de discussion, de sondages, de réunions et de notes d'entrevue. L'étude a révélé que les apprenants et les membres du corps enseignant peuvent avoir des perceptions différentes de l'importance des laboratoires virtuels pour le développement de diverses compétences. À partir des données, cinq thèmes émergent concernant la prise en compte des besoins de divers apprenants et l'utilisation des multiples avantages des laboratoires virtuels. Bien que les laboratoires virtuels de sciences soient perçus comme un outil utile pour l'enseignement et l'apprentissage des sciences, les membres du corps enseignant identifient des obstacles tels que la nécessité de développer des compétences en littératie numérique, une formation initiale et un soutien institutionnel lors de l'introduction de nouveaux outils. Des recommandations pour une intégration efficace des laboratoires virtuels de sciences dans le programme d'études sont incluses.

Mots-clés : développement professionnel des membres du corps enseignant, éducation générale, établissements polytechniques, laboratoires scientifiques virtuels, technologie éducative

Introduction

> When Afton-Dawn Ellison messes up a chemistry experiment, the smoke from the explosion and the shattering glass don't distress her. She simply clicks her computer mouse a few times and starts over. (Carnevale, 2003)

The sudden adjustment to online course delivery during the COVID-19 pandemic may have had a negative and lasting impact on students in postsecondary education in Canada (CDLRA, 2020; OCUFA, 2020). The overall quality of educational experience and the ability to adequately teach and support students led to a pilot project at an Ontarian polytechnic institution in Winter 2021. A group of faculty members, with the support of administration and instructional designers, sought to investigate ways to incorporate virtual science labs developed by Beyond Labz (https://www.beyondlabz.com/). Associated benefits and challenges for faculty members teaching general education and vocational science-related courses are identified.

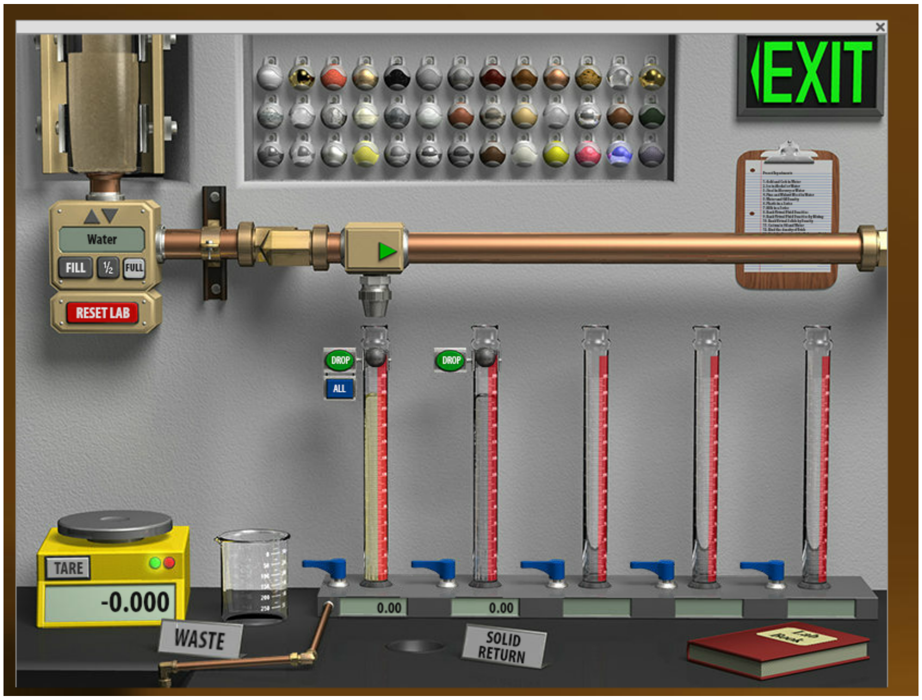
The project consisted of two components:

- Faculty members teaching general education physics and biology courses used virtual labs with students.
- Faculty members from different programs around the college explored Beyond Labz for potential use in their courses.

Beyond Labz is a digital simulation platform built upon actual experimental data and the most advanced models available. This platform offers chemistry, organic chemistry, biology, physics, and physical science labs. Each lab supports hundreds of preloaded experiments and instructors can develop their own activities. For example, Physics Density Lab (Figure 1) supports an experiment in which students are asked to explore the properties of fluids by dropping a Cesium ball into milk (Figure 2). Students press "Drop", and an unexpected explosion occurs (Figure 3).

Figure 1

Screenshot of Density Lab



Note. Density lab, Beyond Labz. Used with permission.

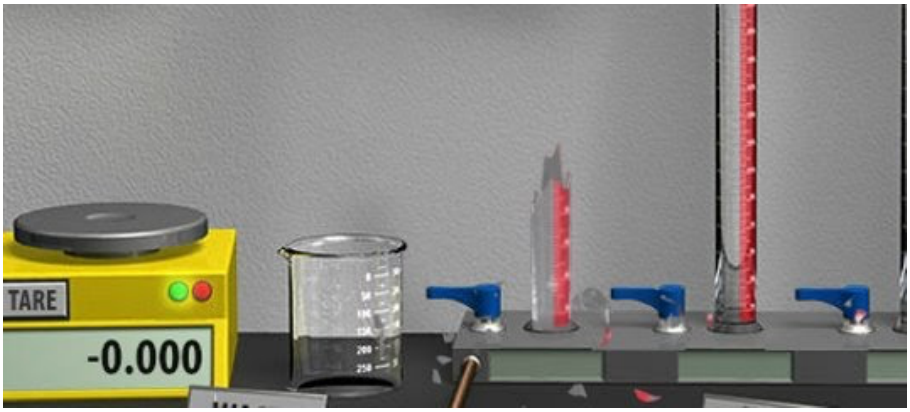
Figure 2

Screenshot of 'Cesium in Milk' Experiment (before)

Note. Density lab, Beyond Labz. Used with permission.

Figure 3

Screenshot of 'Cesium in Milk' Experiment (after)



Note. Density lab, Beyond Labz. Used with permission.

By understanding faculty member experiences with using virtual science labs and simulations, faculty member professional development (PD) is supported. The opportunity for students to enjoy and succeed in college science courses is increased, and career-readiness and soft skills development is promoted. Educators must anticipate the range of needs and then plan accordingly to ensure that faculty members and students can experience the full educational potential of science virtual labs.

Literature Review

As online learning has grown and evolved, so has the use of science virtual labs and simulations. Virtual laboratories (VLs) have become an increasingly viable part of teaching and learning (MERLOT, 2019). Virtual laboratories could be useful resources for science education for remote teaching and have been useful during the COVID-19 lockdowns (de las Heras et al., 2021; Ray & Srivastava, 2020). The need for VLs to be integrated in STEM education became even stronger due to subsequent shift towards online/blended learning (European Commission, 2022). There has been increased focus on the integration of technology to support learning in STEM education research (Pavlou & Zacharia, 2024; Zhan et al., 2022).

The importance of laboratory practice in science studies is acknowledged by the educational research community and the pedagogical value of experiments in science teaching is well established. The importance of experiments has been highlighted by many scientists and educators, all of whom praise the overall benefits of experiments in science teaching and online learning (Faour & Ayoubi, 2018; Papaconstantinou et al., 2020; Potkonjak et al., 2016; Tsichouridis et al., 2019; Waldrop, 2013). Virtual laboratories offer affordances that, in some situations, hands-on labs cannot.

Affordances of Virtual Laboratories

Multiple affordances of science virtual lab technology have been identified. Virtual laboratories:

- support students' deep understanding of science concepts and correcting their misconceptions (Bretz et al., 2013; Bruck et al., 2010; Johnstone & Al-Shuaili, 2001)
- provide easy access to resources anytime and anywhere and flexible user interfaces that meet user needs and expectations (Afgan et al., 2015; Makransky et al., 2016; Viegas et al., 2018)
- can support meaningful learning by linking new information with existing information, thus improving students' conceptual understanding of the material (Aljuhani et al., 2018; Hakím et al., 2016; Papaconstantinou et al., 2020)
- reduce equipment needs and offer students more information and the opportunity to work at their own pace while exploring difficult or interesting concepts (Aljuhani et al., 2018; Darrah et al., 2014; Nickerson et al., 2007; Viegas et al., 2018)
- may be most beneficial for students with special needs (Viegas et al., 2018)
- increase non-cognitive outcomes such as motivation and self-efficacy leading to greater educational and life outcomes (Heckman & Kautz, 2012; Heckman et al., 2006; Makransky et al., 2016)
- may be a good way to conduct problem-based learning and develop analytical thinking skills (Klentien & Wannasawade, 2016)
- can be fun for students as curriculum gamification is added (Aljuhani et al., 2018; Carnevale, 2003)
- used as pre-lab exercises, can alleviate real-lab cognitive workload and increase learning outcomes, giving students an effective way to prepare and gain basic knowledge and cognitive skills beforehand, thereby directing their cognitive resources toward the relevant activity in the real lab (Abdulwahed & Nagy, 2009; Makransky et al., 2016)

Research demonstrates that the combination of virtual and real labs best leverages the different affordances of each lab (Abdulwahed & Nagy, 2009; Corter et al., 2011; de Jong et al., 2013; Makransky et al., 2016; Nickerson et al., 2007; Perkins et al., 2010; Tsichouridis et al., 2019; Zacharia, 2007). Faculty members argue that VLs are preferred when costly apparatuses and supplies are needed, or dangerous experiments are involved. Hands-on labs are also needed to familiarize learners with real-life professional tasks and equipment. In general, teachers report that they do not differentiate between the lab formats and support the fact that both labs are essential to achieve a holistic view of reality (Tsichouridis et al., 2019).

Digital Literacy for Educators

Incorporating VLs in distance learning requires students and teachers to have relevant digital literacy skills. Currently, the discourse on implementing digital technologies in higher education settings focuses more on student learning than on faculty teaching (Guri-Rozenblit, 2018). It is acknowledged that digital literacy skills vary among educators and that not all faculty are digital natives. There is a need to rethink the educators' role in planning and applying technologies to enhance and transform student learning, and to develop ongoing PD to ensure faculty competencies to integrate technologies in their professional practice. The following studies explored teacher digital and media literacy:

- Teachers have low levels of digital safety literacy; facilitating the development of digital literacy is one key challenge faced by schools today, and common teacher technology competencies for teacher education is needed (Borthwick & Hansen, 2017; Tomczyk, 2020).
- Teacher competency to create effective learning environments for students is needed (Hassan & Mirza, 2021; UNESCO, 2018). The main reason for not using technology in schools was the lack of teacher digital skill (Anisimova, 2020; Hassan & Mirza, 2021).
- Teachers reported that digital literacy was a very important skill; 94% of participant teachers reported the need for training (Hassan & Mirza, 2021).
- Borthwick and Hansen (2017) identified that there was little research on effective pre-service teacher preparation in technology use.
- Falloon (2020) provides an extensive analysis of existing digital literacy frameworks and presents a conceptual framework introducing an expanded view of teacher digital competence to better prepare future teachers.
- A digital literacy framework within the teacher education sector including "digital literac(ies) for openness" (Gruszczynska et al., 2013, p. 197) and drawing on socio-cultural models of digital practice has been extensively explored (Davies & Merchant, 2014).
- The Information and Communication Technologies Competency Framework for Teachers explains competencies in use that allow teachers to deliver quality education (UNESCO, 2018).

Research on Virtual Labs

A literature search showed that multiple studies explored the use of VLs and their effectiveness and impact on

a) university students (Afgan et al., 2015; Branan et al., 2016; Corter et al., 2011; Darrah et al., 2014; de las Heras et al., 2021; Makransky et al., 2016; Papaconstantinou et al., 2020; Viegas et al., 2018), and
b) secondary school students (Ambusaidi et al., 2018; Ismail et al., 2016; Perkins et al., 2010; Rajendran et al., 2010; Trúchly et al., 2019).

Also, the topic of student support to use VLs was explored. Zacharia et al. (2015) identified potential types of guidance to support student inquiry when using VLs. Surprisingly, only a few studies explored teacher perspectives on the use of science VLs for teaching and learning (Anisimova, 2020; Guri-Rozenblit, 2018; Hassan & Mirza, 2021; Lima et al., 2019; Makhmudov et al., 2020; Tsichouridis et al., 2019). Technology-enabled teaching and learning, when implemented effectively, has a positive impact on teaching and learning but a negative impact when not implemented appropriately (Bull & Keengwe, 2019; Ma & Nickerson, 2006).

This study helps reduce the research gap by exploring college faculty member perceptions of the efficacy of virtual science labs. These results are relevant to other Canadian polytechnic institutions and can support curriculum integration of science VLs. The objectives of the study include:

- Exploring faculty member perceptions of the efficacy of science virtual labs for general education and applied courses.
- Identifying benefits and challenges in integrating this technology into science college courses.

The Study

Participants

The call for participation was posted on the Microsoft Teams Institutional Community of Practice space in December 2020. Twenty faculty members from different areas of the college attended the briefing session. Ten faculty members remained on the project representing the following areas of the college:

- Liberal Arts and Sciences
- Engineering
- Nursing
- Dental
- Pre-Health
- Instructional Design

Seven faculty members had access to Beyond Labz to explore VLs for potential use in science-related vocational courses. Two faculty members used Physics and Physical Science labs and one used Biology labs for teaching general education courses in Winter 2021. Virtual labs served as live demonstrations during synchronous sessions, as a substitution for hands-on synchronous or asynchronous activities (providing the first-ever labs to this biology course), and as assessment activities (virtual labs were worth 10% of the total course mark). Faculty and an instructional designer met bi-weekly to share their observations, concerns, and successes. Although each faculty member designed their own instructional activities, the ground rules were collaboratively agreed upon (Figure 4) and provided common ground for designing student support and course learning activities and assessment (Figure 5).

Figure 4

Sample Agreed Upon Rules for Virtual Laboratory Integration

- Post information on Blackboard about Beyond labs for students to get familiar with the resource.
- Provide instructions on how to get access to the resource and download labs.
- By week 3 assess the number of students without access to the labs and inform the Project Lead.
- Use virtual labs as instructor's demonstration during live sessions at least one time before the introductory activity.

Note. Author's own image.

Figure 5

Sample Activity Design

Cesium in Oil and Water

Instructions:
Go to "Density" lab. Click on the clipboard in the right top corner of the screen. Open preset list. Then choose "Cesium in Oil and Water" and click on it. All the equipment will be set up.

Purpose:
To explore what happens when you drop cesium metal in oil and water.

Materials:
Two graduated cylinders; olive oil, water, two cesium balls; timer; lab book.

Procedures:
1. Drop the ball in the 1st cylinder. Write down the time it takes to reach the bottom.
2. Drop the ball in the 2nd cylinder. Write down what happens
3. Fill out the table below.
4. Click "Exit" to leave the lab

Data Recording:
Fill out the missing information

Table 2

Cylinder (from left to right)	Liquid type	Liquid volume, ml	Time, seconds
1			
2			

Analysis:

Conclusion:

Note. Author's own image.

Research Design

The present study employed a qualitative research paradigm (Lincoln & Guba, 1985) and a single-case study research design to investigate faculty member perspectives on using science VLs. Selecting a qualitative case study research design allowed research to occur within a real-life context and provided means to deeply understand participants' lived experiences (Merriam, 1998; Yin, 2003), and understand the multiple perspectives that define the phenomena under study (Denzin & Lincoln, 2011).

This study used method triangulation to facilitate the cross-verification of data and represent the participants. Methods of data collection involved a) faculty member pre-survey (Appendix A) and post-survey (Appendix B); b) student post-survey (Appendix C); and c) faculty focus group transcripts, detailed research observation notes; transcripts from four semi-structured interviews with faculty members and peer debriefing. Data collection tools were approved by the Institutional Research Ethics Board. The data was organized around frequently noted topics.

The trustworthiness criteria identified by Lincoln and Guba (1985, 1986) were addressed in the following ways: to improve confirmability, two researchers separately coded the qualitative data, compared codes, and identified themes in data collaboratively; peer-debriefing and an opportunity for participants to review and comment on the accuracy of interpretations and conclusions helped improve researcher reliability and credibility; and the fact that participants represented different areas of the college helped improve transferability and relevance to other Canadian polytechnic institutions.

Findings and Discussion

Pre-survey

A student pre-survey was not conducted. Table 1 shows the pre-survey characteristics of participating faculty (response rate = 100%). Faculty goals for the study included learning about new technology tools for student engagement and active learning, forming a community of practice, and best learning practices. For example, one faculty member responded, "*Find interactive ways to engage learners in class materials; get additional insight into creating immersive online learning activities*", while another wrote, "*To find labs/simulations that will support the theoretical part of the course.*"

Table 1

Characteristics of Faculty Members (n=10)

Characteristic	# of Responses	Percentage
Teaching experience of 6-15 years	6	60%
Teaching experience of 16+ years	4	40%
Have no network of teaching colleagues to share and reflect on best practices for the use of VLs	6	60 %
Have an informal community of practice that meets from time to time	4	40%
Not familiar with VLs	7	70%

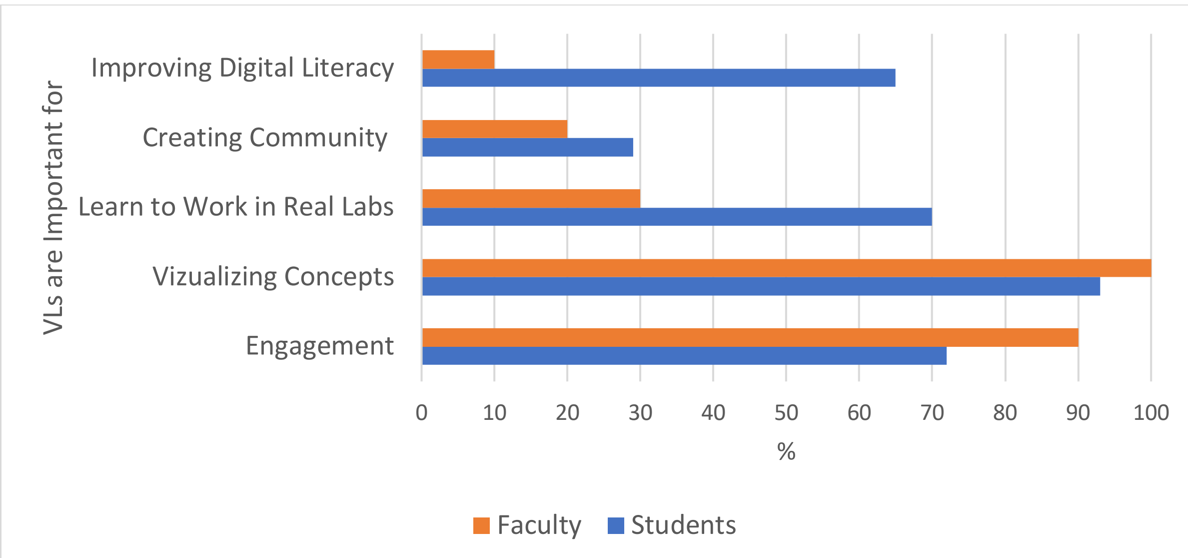
Post-survey

Post-survey response rates for faculty were 100% but only 22% for students. The low student response rate may be due to the length of the survey or because it was a lower priority compared to their vocational courses. Both faculty members and students provided their perspectives on the importance of VLs (Figure 6). The results demonstrated eye-opening perception differences about the value of VLs.

Faculty members perceived VLs as a tool to develop digital literacy and demonstrate how to work in a real lab; much less important than how students perceived VLs. On the other hand, faculty members may overestimate the tool's engagement feature: adding technology to the course does not automatically make it engaging for students. This emphasized the need to relate the choice and use of media to other factors such as learner needs and values, pedagogical context, and learning outcomes in addition to the design of multimedia materials (Bates, 2019).

Figure 6

Comparison of Faculty and Student Perceptions of Affordances of Virtual Labs



Three faculty members, who taught with Beyond Labz, had 135 students in five classes: four sections in a Physics course and one section in a Biology course. Due to the nature of general education courses, students were from a variety of programs and between the first to sixth semesters. Some students decided to forfeit 10% of their course mark to not complete the VLs due to the additional effort required to learn how VLs work.

Analysis of Focus Group Discussions and Meeting Notes

Faculty members suggested that by integrating Beyond Labz into science courses both levels of engagement and opportunity for active learning increased in the classroom. General feedback from faculty members showed that VLs were a good way to engage students with science exploration. One participant stated:

> *I loved the fact that explosions and broken glassware can happen without warning - just like in a real lab. Really made you think about why. Most virtual lab software doesn't allow for this type of "random" effects.*

However, faculty members experienced a learning curve when integrating VLs into their courses. When reflecting upon their experiences, faculty members from applied programs such as dental or nursing reported that due to the nature of their courses and curriculum load, they do not have time ("*unfortunately*") to introduce new tools and teach students how to use them.

Five themes emerged from the data: a) it is important to address diverse student population needs and to consider access and accessibility issues, b) VLs have the potential to enhance learning, c) successful virtual lab integration requires instructional support for students and faculty members alike, d) implementing VLs presents some barriers, and e) it is essential for faculty members to develop digital literacy skills.

These findings agree with findings in other contexts (e.g., Rueda-Gómez et al., 2023). Such similarity, in factors for successful integration of VLs or another online platform in the classroom, suggests that emphasis be placed on adjusting implementation plans and support to the targeted groups. Hence, the types of institutions (e.g., university or polytechnic), the types of students (e.g., taking a diploma or degree program), and course subject matter may be less important.

It is Important to Address Diverse Student Population Needs and to Consider Access and Accessibility Issues

According to the American Council on Education (2019), higher education institutions experience unprecedented diversity of learners. The faculty members mentioned different levels of previous knowledge and different interest levels in learning. One participant highlighted the importance of considering different student attitudes toward learning: VLs as "*assessment will do, optional may ignore*". One faculty member was concerned with "…*different age groups and not curious about digital learning*".

Beyond Labz was designed for university science students majoring in special disciplines who usually start working with VLs and have more background knowledge and lab skills. These students are often more inclined to explore concepts for their own sake. However, based on the data, faculty members recognized that some college students, especially those with previous postsecondary education experience, tended to enjoy the process of exploring the platform while others needed to be scaffolded through the steps. One faculty member shared:

> *For sure, you know as a professor there is a whole range of students. There are for sure students who reach out and they're like, "I got stuck in step one. Help me figure out how to do step two." They want to get it exactly right. So there are for sure that type of students. But I think the software enables the more explorative curious students more than a straight only physical lab does.*

Faculty members who taught using Beyond Labz reported that most students found the platform accessible, while 5% of students did not have access to labs due to technical issues. One faculty member expressed concern that the reason could be that "*students may not have adequate hardware*".

Beyond Labz users needed to install the software on their computer, giving users access to both Desktop and Web versions of the platform. An Internet connection was required to login to the platform, but after that, the labs could be used without Internet. The age and model of a computer or absence of a laptop were some issues reported by students. Learners who did not have access to the resources were given alternative individual or group assignments.

Based on faculty member feedback, the accessibility of a virtual STEM platform and its compliance with WCAG 2.0 (W3C Web Accessibility Initiative, 2021) should be considered during adoption, and plans made for accessibility gaps. Participating instructional designers raised concerns about the Accessibility for Ontarians with Disability Act (AODA, 2005) compliance of Beyond Labz because the tool was originally designed to prioritize realism over accessibility. However, all current and new lab designs are closely aligned to and guided by WCAG 2.0 AA standards (Accessibility Conformance Report, 2020).

Virtual Labs Have the Potential to Enhance Learning

Faculty members reported that the platform can be a useful supplement to real labs, especially for online learning, as it prepares students to apply experiments in real life, after exploring different virtual possibilities and options. One faculty member stated: "*Students can learn to run an experiment, make mistakes, and practice developing critical thinking and problem-solving skills before getting to the "wet" lab."*

Faculty members appreciated "*lots of choice and the fact that they are virtual*" and the "*ability to play with equipment*" in VLs. They explored options for different experiments that could be administered on the platform. One participant described their experience with Beyond Labz as "*no auto-pilot feeling*". The VLs encouraged students to become active learners benefiting from their curiosity and the ability to learn from mistakes. "*They can change/adjust the values for the different variables and compare the results, they can also have recorded results as well".*

Beyond Labz allows students to do science in online courses. As one faculty member wrote, "*Beyond Labz adds a valuable tool to teach the process of science along with the concepts".* Importantly, this tool may be more valuable for general education science college courses ("*with the right faculty training*" as one participant noted) that teach science literacy and do not have restrictive content requirements of applied science college courses. According to one faculty member, "*I would use it for pre-lab activities as well as stand-alone activities and demonstrations*".

Successful Virtual Lab Integration Requires Instructional Support for Students and Faculty

Faculty member feedback emphasized the importance of structured online learning and the need to develop detailed lab manuals to understand how to effectively use VLs. One faculty member pointed out that Beyond Labz is "*not an intuitive platform*", and another confirmed that "*Without a proper tutorial, the interface appears overwhelming and hard to follow*." Another suggested, "*I think a lot more scaffolding and gradual easing into the software is required in the online space*." Another suggested that support is needed for both faculty and students as some students "*want to have someone holding their hand through every step"*.

Implementing Virtual Labs Presents Some Barriers

Many college faculty members are hired because they are professionals in their field. Often, they do not have skills and knowledge in instructional design or special training on VLs in teaching and learning contexts. Time and effort are required to learn new resources. One faculty suggested, *"There is a lot of time and effort that needs to be invested to use these Labz and integrate them into the courses, for the Labz to appear seamless."* Another barrier identified *"The learning curve for creating your own experiments and fear of the unknown"* and concern to "*find balance between direct instructions and real time experience*" was also expressed. Moreover, one participant wrote, "*the perceived level of student support may scare some faculty away from using* [Beyond Labz]*"*.

It is Essential for Faculty Members to Develop Digital Literacy Skills

Bates (2022) emphasized that Canadian colleges and universities need skilled teachers to teach learners the skills needed in the 21st century. Also, it is important to equip learners with the science skills and competencies needed in the digitalized world (Hazelkorn et al., 2015). There is well-established literature and generally agreed best practices (Bates, 2010), but Christensen Hughes and Mighty (2010) found that many faculty members are unaware of these standards. One participant mentioned that a lack of digital skills might be the reason for "*faculty not engaging with the platform*". Many participants agreed that this tool develops creativity in teachers. One participant responded, "*Creative thinking - motivated me to continue to push forward to find technology that supports the pedagogy and curriculum I am working on*".

To fully benefit from using the Beyond Labz platform, participants agreed that faculty members need to upgrade their technology skills to be able to create their own virtual lab content, which will align with course outcomes and serve learners' needs. One faculty member responded, "*I think a lot of teacher training might be required before it is widely adopted*".

Unintended Consequences

One significant finding was the realization of the importance of teamwork. The Professional Learning Community on Microsoft Teams created for the project supported the sharing of ideas, concerns, and various teaching and learning resources, the development of digital literacy, and the building of relationships among participating faculty members. This community was a great way to connect with managers, instructional designers, and other interested faculty members. Members agreed that *"Training on the software and development of custom activities requires time, resources and commitment from their Chairs."*

Recommendations

Recommendations support previous academic research. It is important for faculty members to enhance their media literacy skills and explore different educational platforms (e.g., Gamage et al., 2020). The key is to make the process enjoyable for all educational stakeholders and provide opportunities for peer collaboration. Creating a community of practice within an educational institution is another option for sharing ideas and informal training (Alves et al., 2016). Although opportunity to create a larger community of practice outside a single school may be valuable. In agreement with previous research (e.g., Lima et al., 2019) facilitating ongoing support for faculty members by providing initial training, instructional support, and sharing best practices and activities is needed. It is worth mentioning that resource costs and lack of institutional support may be a barrier to adoption. To find a solution, stakeholders, faculty members, administration, and students should work together to make evidence-based decisions.

Implications

Virtual laboratories and simulations are designed to supplement an already well-designed curriculum and teacher efforts, but they cannot replace them (Perkins et al., 2010). Stöter et al. (2014) suggest research continues to support the adoption of tools that meet the criteria for effectiveness and efficiency in learning experience and outcome. This study contributes to faculty PD literature by unpacking college faculty member perceptions of the efficacy of science VLs and the factors contributing to successful curriculum implementation.

This study offers insight into the implementation process of virtual science labs and identifies the benefits and challenges of using virtual science labs from a faculty member viewpoint. It aims to improve science-education stakeholder knowledge when searching for tools to serve student, faculty member, and institutional needs, and urges more studies to explore the impact of VLs on faculty PD and student learning.

This study demonstrates that with peer support and guidance college faculty may successfully integrate science virtual labs into their courses. For many, teaching with VLs will require stepping outside their comfort zone and experimenting with new teaching techniques. Institutional and provincial support cannot be understated. Preliminary findings suggest that VLs may not be suitable for science courses in vocational programs such as dental or nursing programs because of the intensive nature of these applied programs and the financial cost to the student for such a resource.

This research area is relatively new. There has not been enough data collected to be able to develop a framework for best practices, both in terms of development and VLs use (Brinson, 2017). As a result, it may be difficult to get institutional support for using VLs without evidence to support educational advantages for both faculty members and learners. Deeper exploration of faculty needs for introducing new tech tools into STEM teaching is required.

Three limitations are acknowledged. First, the narrow scope of the study setting. This study takes place in one polytechnic institution in Ontario and may not be representative of other postsecondary institutions in Canada. Beyond Labz may have a greater uptake at the university level due to the nature of their academic and specialist programs and students. Although, colleges of applied arts and technology are focused on career training and trades. Second, the small participant number may limit the transferability or applicability of the findings. The final limitation lies in the probability of the ongoing pandemic affecting both faculty member and student performance and impressions. A long-term research study may provide further insight by allowing for greater knowledge of the context or natural setting, testing different virtual lab vendors, detailing participant backgrounds and experiences, and in turn, opportunities for deeper analysis.

To our knowledge, this study is the first study to analyze the efficacy of virtual labs for science courses at polytechnic institutions in Canada. It addresses the growing need for online formats and is aimed at improving the knowledge base of science education stakeholders. Specific approaches to the integration of VLs needs to be studied to increase their effectiveness. The COVID-19 pandemic has been an important teaching moment for educators around the world that should inform the future design of learning environments and teacher PD, post-pandemic. While apprehension of new technology may cause some teachers to shy away from VLs, the educational advantages offered by this learning platform outweighs initial fears. In addition, the affordances of VLs can address issues around artificial intelligence use in education and academic integrity by providing opportunities for active learning and designing of authentic assessment.

References

Abdulwahed, M., & Nagy, Z. K. (2009). Applying Kolb's experiential learning cycle for laboratory education. *Journal of Engineering Education*, *98*(3), 283–294. https://doi.org/10.1002/j.2168-9830.2009.tb01025.x

Accessibility Conformance Report. (2020). *Beyond Labz*. https://www.calstatela.edu/sites/default/files/groups/Accessible%20Technology%20Initiative/VPAT/bl_vpat_wcag_-_feb_2020.pdf

Afgan, E., Sloggett, C., Goonasekera N., Makunin, I., Benson, D., Crowe, M., Gladman, S., Kowsar, Y., Pheasant, M., Horts, R., & Lonie, A. (2015). Genomics virtual laboratory: A practical bioinformatic workbench for the cloud. *PLoS ONE 10*(10). https://doi.org/10.1371/journal.pone.0140829

Aljuhani, K., Sonbul, M., Althabiti, M., & Meccawy, M. (2018). Creating a Virtual Science Lab (VSL): The Adoption of Virtual Labs in Saudi Schools. *Smart Learning Environments, 5*(16). https://doi.org/10.1186/s40561-018-0067-9

Alves, G. R., Fidalgo, A., Marques, A., Viegas, C., Felgueiras, M. C., Costa, R., Lima, N., Castro, M., Diaz-Orueta, G., San Cristobal Ruiz, E., Garcia-Loro, F., Garcia-Zubia, J., Hernandez-Jayo, U., Kulesza, W., Gustavsson, I., Pester, A., Zutin, D., Schlichting, L., Ferreira, G., … Dobboletta, E. (2016). Spreading remote lab usage a system — A community — A Federation. *2016 2nd International Conference of the Portuguese Society for Engineering Education (CISPEE)*, 1–7. https://doi.org/10.1109/CISPEE.2016.7777722

Ambusaidi, A., Musawi, A. A., Al-Balushi, S., & Al-Balushi, K. (2018). The impact of virtual lab learning experiences on 9th grade students' achievement and their attitudes towards science and learning by virtual lab. *Journal of Turkish Science Education*, *15*(2), 13–29.

American Council on Education. (2019). *Race and Ethnicity in Higher Education Report*. https://www.equityinhighered.org/resources/report-downloads/

Anisimova, E. (2020). Digital Literacy of future preschool teachers. *Journal of Social Studies Education Research, 11*(1), 230–253. https://files.eric.ed.gov/fulltext/EJ1251924.pdf

AODA. (2005). *Ontario*. https://www.ontario.ca/laws/statute/05a11

Bates, A. W. (2022). *Teaching in a digital age* [eBook] (3rd ed.). BCcampus. https://pressbooks.bccampus.ca/teachinginadigitalagev3/

Bates, T. (2010). E-learning quality assurance standards, organizations and research. *Online Learning and Distance Education Resources*. https://www.tonybates.ca/2010/08/15/e-learning-quality-assurance-standards-organizations-and-research/

Borthwick, A. C., & Hansen, R. (2017). Digital literacy in teacher education: Are teacher education competent? *Journal of Digital Learning in Teacher Education, 33*(2), 46–48. https://doi.org/10.1080/21532974.2017.1291249

Branan, D. M., Bennett, P., & Braithwaite, N. (2016). *Remote Access Laboratory Equipment for Undergraduate Science Education*. In D. Kennepohl (Ed.). Teaching Science Online: Practical guidance for effective instruction and lab work. Routledge.

Bretz, S. L., Fay, M., Bruck, L. B., & Towns, M. H. (2013). What faculty interviews reveal about meaningful learning in the undergraduate chemistry laboratory. *Journal of Chemical Education*, *90*(3), 281–288. https://doi.org/10.1021/ed300384r

Brinson, J. R. (2017). A further characterization of empirical research related to learning outcome achievement in remote and virtual science labs. *Journal of Science Education and Technology, 26*(5), 546–560. https://doi.org/10.1007/s10956-017-9699-8

Bruck, L. B., Towns, M., & Bretz, S. L. (2010). Faculty perspectives of undergraduate chemistry laboratory: Goals and obstacles to success. *Journal of Chemical Education*, *8*7(12), 1416–1424. https://doi.org/10.1021/ed900002d

Bull, P. H., & Keengwe, J. (2019). *Handbook of research on innovative digital practices to engage learners*. IGI Global. https://www.igi-global.com/pdf.aspx?tid=232117&ptid=221167&ctid=15&t=Preface&isxn=9781522594383

Carnevale, D. (2003, January 31). The Virtual Lab Experiment. *The Chronicle of Higher Education*, *49*(21). https://www.chronicle.com/article/the-virtual-lab-experiment/

CDLRA. (2020). *2020 National Report*. http://www.cdlra-acrfl.ca/wp-content/uploads/2021/05/2020_national_en.pdf

Christensen Hughes, J., & Mighty, J. (Eds.). (2010). *Taking Stock: Research on Teaching and Learning in Higher Education*. McGill-Queen's University Press. https://www.mqup.ca/taking-stock-products-9781553392712.php?page_id=46

Corter, J. E., Esche S. K., Chassapis, C., Ma, J., & Nickerson, J. V. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers & Education, 57*(3), 2054–2067. https://doi.org/10.1016/j.compedu.2011.04.009

Darrah, M., Humbert, R., Finstein, J., Simon, M., & Hopkins, J. (2014). Are virtual labs as effective as hands-on labs for undergraduate physics? A comparative study at two major universities. *Journal of Science Education and Technology*, *23*(6)*,* 803–814. https://doi.org/10.1007/s10956-014-9513-9

Davies, J., & Merchant, G. (2014). *Digital literacy and teacher education*. In P. Benson & A. Chik (Eds.), Popular Culture, Pedagogy and Teacher Education: International Perspectives (pp. 180–193). Routledge.

de Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science*, *340*(6130), 305–308. https://doi.org/10.1126/science.1230579 de las Heras, S. C., Kensington-Miller, B., Young, B., Gonzales, V., Krühne, U., Mansouri, S. S., & Baroutian, S. (2021). Benefits and challenges of a virtual laboratory in chemical and biochemical engineering: Students' experiences in fermentation. *Journal of Chemical Education, 98*(3), 866–875. https://doi.org/10.1021/acs.jchemed.0c01227

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). *The SAGE Handbook of Qualitative Research*. Sage.

European Commission. (2022). *Impacts of COVID-19 on school education*. Publications Office of the European Union. https://data.europa.eu/doi/10.2766/201112

Falloon, G. (2020). From Digital Literacy to Digital Competence: The Teacher Digital Competency (TDC) Framework. *Educational Technology Research and Development*, *68*, 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Faour, M. A., & Ayoubi, Z. (2018). The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics. *Journal of Education in Science Environment and Health*, *4*(1), 54–68.

Gamage, K. A. A., Wijesuriya, D. I., Ekanayake, S. Y., Rennie, A. E. W., Lambert, C. G., & Gunawardhana, N. (2020). Online delivery of teaching and laboratory practices: Continuity of university programmes during COVID-19 pandemic. *Education Sciences*, *10*(10), 291. https://doi.org/10.3390/educsci10100291

Gruszczynska, A., Merchant, G., & Pountney, R. (2013). Digital futures in teacher education: Exploring open approaches towards digital literacy. *Electronic Journal of e-Learning, 11*(3), 193–206. https://academic-publishing.org/index.php/ejel/article/view/1669

Guri-Rozenblit, S. (2018). E-Teaching in higher education: An essential prerequisite for e-learning. *Journal of New Approaches in Educational Research, 7*(2)*,* 93–97. https://doi.org/10.7821/naer.2018.7.298

Hakím, A., Liliasari, Kadarohman, A., & Syah, Y. M. (2016). Effects of the Natural Product Mini Project Laboratory on the Students' Conceptual Understanding. *Journal of Turkish Science Education*, *13*(2)*,* 27–36. https://www.tused.org/index.php/tused/article/view/640

Hassan, M. M., & Mirza, T. (2021). The Digital Literacy in Teachers of the Schools of Rajouri (J&K)-India: Teachers Perspective. *International Journal of Education and Management Engineering, 11(1),* 28–40. https://doi.org/10.5815/IJEME.2021.01.04

Hazelkorn, E., Ryan, C., Beernaert, Y., Constantinou, C. P., Deca, L., Grangeat, M., Karikorpi, M., Lazoudis, A., Casulleras, R. P., & Welzel-Breuer, M. (2015). *Science Education for Responsible Citizenship*. Report to the European Commission of the Expert Group on Science Education, Directorate-General for Research and Innovation, Science with and for Society. Publications Office of the European Union. https://www.academia.edu/14816833/Science_Education_for_Responsible_Citizenship

Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour Economics,19*(4), 451–464. https://doi.org/10.1016/j.labeco.2012.05.014

Heckman, J. J., Stixrud, J., & Urzua, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics, 24*(3). https://doi.org/10.1086/504455

Ismail, I., Permanasari A., & Setiawan, W. (2016). Stem Virtual Lab: An alternative practical media to enhance student's scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 239–246. https://doaj.org/article/71caf862c64b4e648411e6b98f12c468

Johnstone, A. H., & Al-Shuaili, A. (2001). Learning in the laboratory; Some thoughts from the literature. *University Chemistry Education, 5*(2), 42–51.

Klentien, U., & Wannasawade, W. (2016). Development of blended learning model with virtual science laboratory for secondary students. *Procedia – Social and Behavioral Science, 217,* 706–711. https://doi.org/10.1016/j.sbspro.2016.02.126

Lima, N., Viegas, C., & García-Peñalvo. F. J. (2019). Different Didactical Approaches Using a Remote Lab: Identification of Impact Factors. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje 14(*3), pp 76–86. https://doi.org/10.1109/RITA.2019.2942256

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.

Lincoln, Y. S., & Guba, E. G. (1986). But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation [Abstract]. *New Directions for Program Evaluation, 30,* 73–84. https://doi.org/10.1002/ev.1427

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys 38*(3), 1–24. https://doi.org/10.1145/1132960.1132961

Makhmudov, K., Shorakhmetov, S., & Murodkosimov, A. (2020). Computer literacy is a tool to the system of innovative cluster of pedagogical education. *European Journal of Research and Reflection in Educational Sciences, 8*(5).

Makransky, G., Thisgaard, M. W., & Gadegaard, H. (2016). Virtual simulations as preparation for lab exercises: Assessing learning of key laboratory skills in microbiology and improvement of essential non-cognitive skills. *PLoS ONE, 11*(6). https://doi.org/10.1371/journal.pone.0155895

MERLOT. (2019). *Virtual Labs for the MERLOT Community*. https://virtuallabs.merlot.org/

Merriam, S. B. (1998). *Qualitative Research and Case Study Applications in Education*. Jossey-Bass.

Nickerson, J. V., Corter, J. E., Esche, S. K., & Chassapis, C. (2007). A model for evaluating the effectiveness of remote engineering laboratories and simulations in education. *Computers & Education, 49*(3)*,* 708 -725. https://doi.org/10.1016/j.compedu.2005.11.019

OCUFA. (2020, November). *Study: COVID-19 and the Impact on University Life and Education*. https://ocufa.on.ca/assets/OCUFA-2020-Faculty-Student-Survey-opt.pdf

Papaconstantinou, M., Kilkenny, D., Garside, C., Ju, W., Najafi, H., & Harrison, L. (2020). Virtual lab integration in undergraduate courses: Insights from course design and implementation. *Canadian Journal of Learning and Technology, 46*(3). https://doi.org/10.21432/cjlt27853

Pavlou, Y., & Zacharia, Z. C. (2024). *Using Physical and Virtual Labs for Experimentation in STEM+ Education: From Theory and Research to Practice*. In K. Korfiatis, M. Grace, M. Hammann, (Eds.) Shaping the Future of Biological Education Research. (pp. 3–19). Springer. https://doi.org/10.1007/978-3-031-44792-1_1

Perkins, K. K., Loeblein, P. J., & Dessau, K. L. (2010). Sims for Science: Powerful tools to support inquiry-based teaching. *The Science Teacher*, *77*(7), 46–51.

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education, 95,* 309–327. https://doi.org/10.1016/j.compedu.2016.02.002

Rajendran, L., Veilumuthu, R., & Divya, J. (2010). A study on the effectiveness of virtual lab in e-learning. *International Journal on Computer Science and Engineering, 2*(6), 2173–2175.

Ray, S., & Srivastava, S. (2020). Virtualization of science education: A lesson from the COVID-19 pandemic. *Journal of Proteins and Proteomics, 11*, 77–80. https://doi.org/10.1007/s42485-020-00038-7

Rueda-Gómez, K. L., Rodríguez-Muñiz, L. J., & Muñiz-Rodríguez, L. (2023). Factors that mediate the success of the use of online platforms to support learning: The view of university teachers. *Education and Information Technologies, 29*, 2459–2482. https://doi.org/10.1007/s10639-023-11916-0

Stöter, J., Bullen, M., Zawacki-Richter, O., & von Prümmer, C. (2014). *From back door into the mainstream: The characteristics of lifelong learners*. In O. Zawacki-Richter and T. Anderson (Eds.). Online Distance Education: Towards a Research Agenda (pp. 421–457). AU Press. https://www.aupress.ca/books/120233-online-distance-education/

Tomczyk, Ł. (2020). Skills in the area of digital safety as a key component of digital literacy among teachers. *Education and Information Technologies. 25*, 471–486. https://doi.org/10.1007/s10639-019-09980-6

Trúchly, P., Medvecký, M., Podhradský, P., & Mawas, N. E. (2019). STEM education supported by virtual laboratory incorporated in a self-directed learning process. *Journal of Electrical Engineering, 70*(4). https://doi.org/10.2478/jee-2019-0065

Tsichouridis, C., Vavougios, D., Batsila, M., & Ioannidis, G. (2019). The optimum equilibrium when using experiments in teaching – Where virtual and real labs stand in science and engineering teaching practice. *International Journal of Emerging Technologies in Learning*, *14*(23), 67–84. https://doi.org/10.3991/ijet.v14i23.10890

UNESCO. (2018). *ICT Competency Framework for Teachers*. https://en.unesco.org/themes/ict-education/competency-framework-teachers

Viegas, C., Pavani, A., Lima, N., Marques, A., Pozzo, I., Dobboletta, E., Atencia, V., Barreto, D., Calliari, F., Fidalgo, A., Lima, D., Temporão, G., & Alves, G. (2018). Impact of a remote lab on teaching practices and student learning. *Computers & Education, 126*, 201–216. https://doi.org/10.1016/j.compedu.2018.07.012

W3C Web Accessibility Initiative. (2021). https://www.w3.org/WAI/

Waldrop, M. M. (2013). The virtual lab: confronted with the explosive popularity of online learning, researchers are seeking new ways to teach the practical skills of science. *Nature, 499*(7458), 268+. https://link.gale.com/apps/doc/A337370661/HRCA?u=anon~a43d1215&sid=googleScholar&xid=79ae2d86

Yin, R. K. (2003). *Case Study Research: Design and Methods*. (3rd ed.). Sage.

Zacharia, Z. C. (2007). Comparing and combining real and virtual experimentation: an effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning*, *23*(2), 120–132. https://doi.org/10.1111/j.1365-2729.2006.00215.x

Zacharia Z. C., Manoli, C., Xenofontos, N., de Jong, T., Pedaste, M., van Riesen, D. A. N., Kamp, E. T., Mäeots, M., Siiman, L., & Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: a literature review. *Education Technology Research and Development, 63*, 257–302. https://doi.org/10.1007/s11423-015-9370-0

Zhan, Z., Shen, W., Xu, Z., Niu, S., & You, G. (2022). A bibliometric analysis of the global landscape on STEM education (2004–2021): Towards global distribution, subject integration, and research trends. *Asia Pacific Journal of Innovation and Entrepreneurship, 16*(2), 171–203. https://doi.org/10.1108/APJIE-08-2022-0090

Appendix A: Faculty Pre-survey

1. Please provide some background information on your years of teaching experience.
2. What science virtual labs would you like to test? Select everything that apply.
    a. Biology
    b. Chemistry
    c. Organic chemistry
    d. Physical science
    e. Physics
3. How familiar are you with virtual labs and/or simulations?
    a. Not at all familiar
    b. Not so familiar
    c. Familiar
    d. Very familiar
    e. Extremely familiar
4. What virtual labs or simulations do you currently use in your courses, if any? Write the name of the resource and ways you use it in the classroom.
5. Do you have a network of teaching colleagues (i.e., a community of practice) to share/reflect with on best practices and generate novel, creative ideas for incorporating.
    a. Yes
    b. No
6. What are your own professional learning goals in participating in this pilot?

Appendix B: Faculty Post-survey

Introduction

1. How familiar are you with virtual labs and/or STEM simulations?
    a. not at all familiar
    b. slightly familiar
    c. moderately familiar
    d. very familiar
    e. extremely familiar
2. How important are virtual labs for STEM general education courses?
    a. Unimportant
    b. Slightly important
    c. Moderately important
    d. Important
    e. Very important
3. What are some of the virtual labs and/or simulations you use the most?
4. What do you like or dislike about these resources?
5. How often do you currently use virtual labs and/or simulations in the courses you teach?
    a. Never
    b. Rarely
    c. Sometimes
    d. Often
    e. Always
6. Please provide some examples of how you use virtual labs and/or simulations in your courses. For example, as pre-lab activities, wet lab replacement, etc.

Beyond Labz Specific Questions

7. What virtual labs did you try?
8. Rate your overall experience with Beyond Labz
    a. Very poor
    b. Poor
    c. Fair

    d. Good
    e. Excellent

9. What did you like most about them?
10. What did you like least about them?
11. Comment on overall quality of this resource for STEM college courses
    a. Very poor
    b. Poor
    c. Fair
    d. Good
    e. Excellent

Opportunity Questions

12. Beyond Labz virtual labs is a good way to engage students with science exploration.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
13. Would you use this product today?
    a. Definitely not
    b. Probably not
    c. Possibly
    d. Probably
    e. Definitely
14. How might you integrate the Beyond Labz STEM virtual labs into your courses? Provide examples of activities.
15. What might keep faculty from using Beyond Labz virtual labs?

Reaction Questions

16. What is the most appealing about Beyond Labz virtual labs?
17. What is the hardest part about using this resource?
18. Was there anything surprising or unexpected about this resource?

19. What could be done to improve this product?
20. Was there anything missing from this product that you expected?

User experience

21. The resource has a user-friendly interface.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
22. The resource is easy to navigate.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
23. The resource support/help is effectively organized.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
24. The resource pages generally have good image quality.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
25. The resource has pleasing appearance.
    a. Strongly disagree
    b. Disagree

c. Neutral

d. Agree

e. Strongly agree

26. The resource has real wet lab feeling to it.

a. Strongly disagree

b. Disagree

c. Neutral

d. Agree

e. Strongly agree

Appendix C: Student Post-survey

Introduction

1. How familiar are you with virtual labs and/or STEM simulations?
    a. Not at all familiar
    b. Slightly familiar
    c. Moderately familiar
    d. Very familiar
    e. Extremely familiar
2. How important are virtual labs for STEM general education courses?
    a. Unimportant
    b. Slightly important
    c. Moderately important
    d. Important
    e. Very important
3. What are some of the virtual labs and/or simulations you have used in your college courses?
4. What do you like or dislike about these resources?
5. Have you worked with virtual labs and/or simulations in other courses this semester? If yes, then explain.

User experience

6. The resource has a user-friendly interface.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
7. The resource is easy to navigate.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree

    e. Strongly agree

8. The resource support/help is effectively organized.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
9. The resource pages generally have good image quality.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
10. The resource has pleasing appearance.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
11. The resource has real wet lab feeling to it.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

Reaction Questions

12. What is the most appealing about Beyond Labz virtual labs?
13. What is the hardest part about using this resource?
14. Was there anything surprising or unexpected about this resource?
15. What could be done to improve this product?

16. Beyond Labz virtual labs is a good way to engage students with science exploration.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

Beyond Labz Specific Questions

17. What virtual labs did you try?
    a. Biology
    b. Chemistry
    c. Physics
18. Rate your overall experience with Beyond Labz
    a. Very poor
    b. Poor
    c. Fair
    d. Good
    e. Excellent
19. What did you like most about them?
20. What did you like least about them?

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