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The Use of Virtual Research Experiences for Appalachian Career Training in Oncology (ACTION) Program High School Participants During the COVID-19 Pandemic

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ABSTRACT: Kentucky has the highest cancer incidence and mortality rates in the nation, with rates greatest in the Appalachian region due to poor health behaviors and inequities in social determinants of health. The Appalachian Career Training in Oncology (ACTION) Program at the University of Kentucky Markey Cancer Center engages 20 Appalachian-native high school students annually in cancer education, research, and outreach activities. During the COVID-19 pandemic, programming was disrupted, and alternative activities were implemented, including virtual research experiences. The program's goals were to improve students' biology and cancer content knowledge and research skills and help students make career decisions. Virtual laboratories were used to help accomplish these goals. This study aimed to evaluate the use of virtual laboratories embedded in the program and determine if such experiences helped reach the program's goals. A survey was used to measure students' perceptions of the virtual labs. Results indicated that students perceived they gained content knowledge, obtained research skills, and considered entering science and cancer-related careers. The decision to incorporate virtual laboratories into the ACTION programming during the COVID-19 pandemic was a sound instructional choice. Evidence provided herein gives researchers and program developers information necessary to consider using virtual labs in their programs.

INTRODUCTION

Kentucky leads the nation in cancer incidence and mortality rates (ACS, 2021; NCI, 2021; Siegel et al., 2021). In particular, Appalachian Kentucky has a 36.53% higher cancer mortality rate than the national average and a 17.88% higher mortality rate than non-Appalachian Kentucky (Rodriguez et al., 2018). Many of these cancers are preventable through effective management of risk factors and education interventions (Rodriguez et al., 2018; Williams et al., 2021). In addition to the disparities in cancer incidence and mortality between Appalachian Kentucky and non-Appalachian regions, educational disparities exist between the Appalachian region and the rest of the state. For example, the percentage of adults ages 25 and up with less than a high school diploma is higher in Appalachian Kentucky (21%) compared to the rest of the state (11.1%) (ARC, 2021a). There are also fewer adults (ages 25 and up) in Appalachian Kentucky (79%) who have obtained a high school diploma compared to the rest of the state (88.9%) (ARC, 2021a). Statistics such as these motivated the Markey Cancer Center (MCC) at the University of Kentucky (UK) to develop the Appalachian Career Training in Oncology (ACTION) Program.

The ACTION Program was established at UK in 2016 to prepare Appalachian Kentucky high school and undergraduate students to pursue cancer-focused careers using culturally appropriate educational methods. The program provides opportunities for Appalachian Kentucky students to gain experience in cancer research, clinical settings, and education and outreach. To date, ACTION has successfully engaged six cohorts of undergraduates and two cohorts of high school students. ACTION undergraduates are enrollees at UK and participate in activities year-round. In contrast, ACTION high school students engage in monthly activities during the academic year and in a residential summer program, where they participate in mentored research projects, shadowing experiences, cancer education and career development workshops, and outreach opportunities. The components and early outcomes of the ACTION Program have recently been described elsewhere (McConnell Parsons et al., 2021).

The COVID-19 pandemic disrupted ACTION programming throughout 2020 – 2021, with the most significant disruption occurring for high school students; the 2020 high school summer residential program was canceled, and the 2021 summer program occurred in a hybrid format, with the first part of the program occurring virtually followed by a modified version of the residential program. Students were not allowed to enter research or clinical settings during the pandemic despite being on UK's campus in the summer of 2021; thus, using virtual laboratories could provide students with cancer-related research and training experiences.

Science educators have been using multiple technology modalities in the classroom for years, but due to pressures caused by the COVID-19 pandemic, the use of virtual laboratories has accelerated. Ray and Srivastava (2020) suggested that educational institutions tried to circumvent the crisis brought on by the pandemic "by moving the essential educational missions into a virtual environment" (p. 77). To maintain instructional programs, instructors looked for inexpensive, scalable, and easily employed online laboratory infrastructure, which they could adapt to fulfill learners' needs during the pandemic (Jackson and Rudaitis, 2020). During the pandemic, the urgency and shift to alternate platforms for hands-on science instruction left educators and students unprepared with fewer resources of unknown quality.

The leadership of the ACTION program strongly considered the use of virtual laboratories in the ACTION program as an alternative to in-person instruction and developed criteria for selecting vendors. The program director was looking for virtual labs that were relatively inexpensive and could easily be accessed in a rural region with known Internet connectivity limitations. In addition, he wanted a program with content that was relevant to the ACTION program, accessible to Appalachian students, and organized in short units that could be completed in hour-long segments. Last, the director wanted virtual programs to have content assessments, graphical models of actual experiments, and engaging research questions.

Problems of Internet connectivity were foremost on the director's list of criteria because of reports of Internet limitations in eastern Kentucky. The Kentucky Department of Education reports that the commonwealth has 700,000 computing devices in the K-12 schools and that 81% of Kentucky students find it easy to collaborate using online documents, 72% read content online at least once a week, and 70% say it is easy to edit a photo (Kentucky Teacher, 2020). However, while students have computer access at school, digital access is not ubiquitous in Kentucky households where the ACTION program took place. During the 2015-2019 period, 78% of Appalachian households had a broadband Internet subscription, compared to 83% of households nationwide. The Appalachian Regional Commission (ARC) reports that a rural-urban "digital divide" exists. In 18 Appalachian counties, more than half of which are considered rural, less than 60% of households had a broadband subscription. For Kentucky, the ARC reports that 71% of Appalachian communities have broadband subscriptions, whereas 81% of non-Appalachian communities have broadband. They also report that 19.5% of Appalachian communities are without a computer device (ARC, n.d.).

Online courses, live streaming, virtual teaching, and simulated labs serve as alternatives to in-class science instruction so students can learn from home while maintaining a safe distance (Sandipan Ray and Srivastava, 2020). To determine the extent to which STEM outreach programs altered their programming due to COVID-19, STEM outreach directors from Vanderbilt and West Virginia Universities (Ufnar et al., 2021) collected information from sixty-one program directors who described 115 outreach projects across the US. More than 80% of directors indicated they changed their program to take advantage of virtual methodologies. Two important themes emerged from their analyses: program adaptation and challenges to implementation. A total of 66 secondary comments under program adaptation mentioned kits dropped at public sites or mailed directly to participants. Sixteen examples of virtual laboratories substituting for on-campus student research were identified, including approaches such as simulated labs and data collection and analysis, and Labster was specifically mentioned. Another common theme recounted by directors was the importance of connections, including student-student, teacher-teacher, teacher-researcher, and mentoring. Ufnar et al. (2021) mentioned connections among participants due to the challenges of maintaining personal connections through virtual platforms. Several project managers specifically focused on personal and professional connections and highlighted how their program maintained or increased these connections.

Many researchers have investigated the benefits and drawbacks or challenges of virtual labs. For example, de Jong et al. (2013) compared physical and virtual laboratories, reporting that physical and virtual laboratories can achieve similar objectives, such as exploring the nature of science, cultivating interest in science, and promoting conceptual understanding. De Jong and his team stated that when students used physical equipment, they developed laboratory skills and experienced the challenges scientists faced when planning experiments. Virtual experiments offer efficiencies over physical experiments because they often require less setup time and quickly provide results of lengthy investigations, enabling students to perform more experiments and gather more information. Furthermore, during physical investigations, students learn about the complexities of science by dealing with unanticipated events, whereas, in virtual laboratories, students are not distracted by anomalies in equipment or unanticipated consequences.

However, challenges do exist when implementing virtual laboratories. Jackson and Rudaitis (2020) noted that transitioning laboratory-based exercises to online environments is difficult, time-consuming, and sometimes costly when classroom-ready commercially produced virtual laboratories are not available. Gorghiu et al. (2009) noted disadvantages of virtual chemistry instruction, including students' lack of skill acquisition regarding chemical equipment and manipulation of chemical reagents and lack of careful observations of chemical phenomena. Chan and Fok (2009) suggest that virtual programs can also discourage students from becoming familiar with physical instruments and real devices. Moreover, skills such as teamwork and communication, which can develop in traditional laboratory training, might not be fostered through remote or virtual laboratory training.

Numerous researchers have addressed the question of the academic effectiveness of virtual laboratories, and the body of research is mixed. For example, Wiesner and Lan (2004) compared the use of virtual and physical equipment in a senior operations laboratory. Results indicated that student learning was similar for both methods. Zacharia and Constantinou (2008) reported no differences between virtual and physical experiments on tests of conceptual understanding for undergraduates learning thermodynamics concepts. Their study revealed that virtual and physical manipulatives could effectively develop conceptual understanding.

One remaining key issue regarding virtual laboratories may be the balance between virtual and in-person investigations for courses or programs. Instructional designers or program specialists may improve learning outcomes by taking advantage of each method's strengths. Whether virtual labs can completely replace physical labs remains a matter of argument, but a combination of both is undoubtedly valued in science education (de Jong et al., 2013).

After carefully considering of multiple options and ACTION program goals, two virtual labs became part of the 2021 ACTION program, Labster and eCLOSE Institute (hereafter referred to as eCLOSE), complementing other cancer-related educational activities. Labster is an online platform that provides interactive, advanced lab simulations. The simulations contain gamification elements (such as 3D universe and storytelling) to engage students' curiosity, demonstrate the content application, and highlight scientific concepts. Labster has over 200 biology, chemistry, engineering, medicine, and physics simulations, with numerous packages within each subject area (Labster, 2022a).

eCLOSE was the second virtual laboratory used within the ACTION program. eCLOSE is a non-profit, citizen science organization that uses *Drosophila* as a model system to engage participants in hands-on cancer genetics experiments (eCLOSE Institute, 2022). In response to the COVID-19 pandemic, eCLOSE adapted their summer program to a hybrid format in which students received a Lab-in-a-Box for use in their homes along with the eCLOSE Camp@Home curriculum. In conjunction with real-time, online instruction from eCLOSE scientist-science teacher teams, these experimental kits allowed participants to apply science process skills to research projects in the safety of their own homes.

This study aimed to evaluate whether the two virtual labs would be an acceptable way to conduct ACTION instruction, especially during crisis events such as the COVID-19 pandemic. More specifically, it was to determine if the virtual labs improved students' biology and cancer content knowledge, research skills, motivation to learn, and influenced students' career decisions. Findings from this study contribute to understanding how virtual labs can be used in cancer-education outreach programs.

METHODS

Participants. Twenty high school students from Appalachian Kentucky participated in the 2021 ACTION Program. See Table 1 for participant demographics. Participants were all freshman and sophomores and almost evenly divided between male (45%) and female (55%). All students were White and resided in counties classified as economically distressed or at-risk for distressed county status (ARC, 2021b). Almost half the students (45%) were first-generation students, and 20% were classified as low-income. These demographics are closely aligned with the Appalachian Kentucky region (Pollard and Jacobsen, 2020).

Table 1. *Demographics of Participating ACTION High School Students (N = 20).*

Parameter	Category	Frequency	Percent
Academic Level	Freshman	9	45
	Sophomore	11	55
Gender	Male	9	45
	Female	11	55
Race/Ethnicity	White	20	100
	African American/Black	0	0
	American Indian/Alaska Native	0	0
	Asian	0	0
	Hispanic or Latino	0	0
	Not Hispanic or Latino	20	100
Disparity Status	County is classified as distressed or at-risk	20	100
	First Generation Student	9	45
	Low Income Status*	4	20
	From Rural County**	20	100

**Low income status was identified through self-reported taxable income. Low-income levels are those defined by the US Census Bureau. **Rural areas are as designated by the Health Resources and Services Administration.*

Procedure. Students in the 2021 ACTION program participated in the Labster simulations and the eCLOSE Labs-in-a-Box activities. Each participant was tasked with completing 11 Labster simulations from their home computers. The ACTION program director chose the simulations based on how they would complement ACTION didactic programming. Labster sent each student login information to access the simulations. The simulations were scheduled for nine 45-minutes sessions (~7 hours) throughout the 5-week summer program (~125 hours), which represented 5.6% of the program's instructional time.

eCLOSE activities took place over Zoom; therefore, the ACTION program staff sent students a Zoom link so they could participate in relevant programming. Students participated through Zoom from their home computers. Students received Labs-in-a-Box from eCLOSE, which allowed them to perform experiments with fruit flies (*Drosophila melanogaster)*. Students observed the relationship between tobacco and cancer by incorporating tobacco into the fruit flies' diet. The fruit flies had different genotypes, and the goal was to determine how different mutations affected the flies' fertility or mortality when different forms of tobacco were introduced into the flies' diet. The tobacco-related project was chosen based on associations with cancer and cultural connections of high tobacco use in Appalachian Kentucky. To summarize their findings, eight small groups of two to three students reported their findings through Zoom. eCLOSE activities were scheduled for five 3-hour blocks every afternoon (15 hours) Monday through Friday, during week three of the program, representing 12% of the program's instructional time.

Measures. Two Likert scale-type instruments, *Perceptions of the Labster Program* (Supplemental Material 1) and *Perceptions of the eCLOSE Program* (Supplemental Material 2), were used to measure students' perceptions of the virtual labs. The surveys were developed by the ACTION Program director and were administered through REDCap (Harris et al., 2009), hosted at UK, and sent to students after the program. The *Perceptions of the Program Surveys* were composed of five subscales determined by the developer's intent and expertise of the evaluator; an exploratory factor analysis was not conducted because of the small sample size. Subscales were *Biology and Cancer Knowledge Content*, *Motivation to Learn*, *Research Skills*, *Ease of Use*, and *Career Decisions*. Each item on the Perceptions of the Program subscales had five response options, strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5).

Additionally, the *Perceptions of the Program Surveys* contained open-ended questions to allow additional feedback. Students were asked to 1) provide any positive comments regarding their experience with Labster; 2) provide any negative comments regarding their experience with Labster; 3) provide a reason for not completing all simulations; and 4) provide any other comments or feedback about Labster. Similar questions were asked about the eCLOSE program.

Data Analysis. Classical test theory (CTT) analyses were conducted in SPSS (2021) to provide an item analysis on the Perceptions of the Program Surveys. Inter-item correlations, corrected item-total correlations, and alpha-if item deleted statistics were used to assess the quality of items. Internal consistency, Cronbach's alpha (α), and related confidence intervals of each subscale were determined. Subscales were used to calculate Cronbach's alpha to increase the ratio of respondents to the number of items, and confidence intervals were used to show the precision of the internal consistency estimates. The small sample sizes of this study impacted all statistical analyses, which includes Cronbach's alpha. However, Cronbach's alphas and confidence intervals were calculated for descriptive purposes only and not for hypothesis testing. Although no definitive guideline has been established, Nunnally (1978) suggests a minimum level of $\alpha = 0.70$ for basic research. Cronbach's alpha coefficients for subscales with high internal consistency and narrow confidence intervals were compared to determine if there were significant differences between the Cronbach's alphas, using cocron, version 1.0-1 (Diedenhofen and Musch, 2016), a software package in *R* (R Core Team, 2021).

The percent of each response option for each *Perceptions of the Program Surveys* item was reported. The means of Labster and eCLOSE subscales with high reliability and narrow confidence intervals were compared using one-way repeated measures ANOVA. All qualitative data were analyzed through template analysis. In a template analysis, the researcher uses a template of themes developed a priori to do an initial coding. The coding template is iteratively revised and refined (Brooks et al., 2015).

A reading level analysis was conducted on a small portion of one Labster simulation, *Signal Transduction: Choose the best cancer inhibitor* (Labster, 2022b), using a Flesch Kincaid Readability calculator (Good Calculators, 2021).

RESULTS

This paper aimed to evaluate the use of two virtual labs embedded in the ACTION program and determine if they improved students' biology and cancer content knowledge, research skills, motivation to learn, and influenced students' career decisions. The results section is organized around these topics.

Cronbach's alpha for the *Perceptions of the Labster Program Subscales* ranged from $\alpha = 0.925$, 95% CI [0.390, 0.971] (*Biology and Cancer Content Subscale*) to $\alpha = 0.427$, 95% CI [-0.48, 0.77] (*Motivation Subscale*). Cronbach's

Table 2. *Subscale Item Analysis Data.*

Subscales	Instrument Item	Corrected item-total correlation range	Cronbach's alpha	95% Confidence intervals with 500 bootstrap samples	
				Lower Limit	Upper Limit
Labster Subscales					
Biology and Cancer Content Knowledge	1, 2, 16, 17	0.776 to 0.915	0.925	0.390	0.971
Motivation to Learn	3, 4, 13	0.018 to 0.515	0.427	-0.48	0.77
Research Skills	6, 7, 10, 11, 12	0.155 to 0.805	0.740	0.284	0.882
Ease of Use	14, 15, 23, 24	0.252 to 0.698	0.684	0.164	0.865
Career Decisions	19, 20, 21, 22	0.546 to 0.768	0.831	0.289	0.961
Overall Experience	8, 9, 18, 25	0.400 to 0.755	0.726	-0.28	0.910
eCLOSE Subscales					
Biology and Cancer Content Knowledge	1, 2, 16, 17	0.762 to 0.842	0.905	0.364	0.969
Motivation to Learn	3, 4, 13	0.427 to 0.686	0.701	-0.037	0.896
Research Skills	5, 6, 7, 10, 11, 12	0.754 to 0.943	0.942	0.884	0.963
Ease of Use	14, 15	0.943	0.941	Would not converge	
Career Decisions	19, 20, 21, 22	0.750 to 0.950	0.938	0.736	0.994
Overall Experience	8, 9, 18, 25	0.646 to 0.862	0.872	0.204	0.967

alpha for the *Perceptions of the eCLOSE Program Subscales* ranged from α = 0.942, 95% CI [0.364, 0.969] (*Research Skills Subscale*) to α = 0.701, 95% CI [-0.037, 0.896] (*Motivation Subscale*). Other item-analysis data can be found in Table 2.

The Cronbach's alpha confidence intervals for three subscales (*Motivation to Learn*, *Ease of Use*, and *Overall Experience*) were very wide, indicating a lack of precision or an instability in the estimates. The confidence intervals for the remaining subscales (*Biology and Cancer Content Knowledge*, *Research Skills*, and *Career Decisions*) were narrower and thus more stable. It is apparent that the small sample sizes impacted the precision of the Cronbach's alpha estimates. Although most of the Cronbach's alpha coefficients for the eCLOSE subscales were higher than their respective Labster subscale coefficients, significance tests were applied to compare the internal consistencies (Diedenhofen and Musch, 2016); however, no significant differences were detected ($\alpha_{Labcontent} = 0.925$, $\alpha_{eCcontnet} = 0.905$, $\chi^2 = 0.0704$, df = 1, $p = 0.7907$; $\alpha_{LabRS} = 0.740$, $\alpha_{eCRS} = 0.942$, $\chi^2 = 2.8939$, df = 1, $p = 0.0889$; $\alpha_{LabCD} = 0.831$, $\alpha_{eCCD} = 0.938$, $\chi^2 = 1.3237$, df = 1, $p = 0.2499$).

The readability analysis of a portion of the Labster simulation, *Signal Transduction: Choose the best cancer inhibitor* (Labster, 2022b), showed a difficult reading level (44.6 – college) and average words per sentence of 18. Although 18 is not a large number, there is a correlation between readability and sentence length: As average sentence length increases, the grade level required to read the text also increases (Orpheus Technology, 2022).

Table 3 shows student response frequencies for each item by subscale and mean frequencies for each subscale for the *Perceptions of the Labster Program Survey*, whereas Table 4 shows responses for the *Perceptions of the eCLOSE Program Survey.*

Biology and Cancer Content Knowledge. Students responded positively to many *Labster Biology and Cancer Content Knowledge Subscale* items ($M_{agree} = 62.50\%$, $M_{strongly\ agree} = 27.10\%$). For instance, Labster1, "Provided relevant biology content" (Agree = 50%, Strongly Agree = 41.7%), and Labster16, "Helped me understand cancer processes" (Agree = 66.7%, Strongly Agree = 25%). Responses were similar for the *eCLOSE Biology and Cancer Content Knowledge Subscale* ($M_{agree} = 47.5\%$, $M_{strongly\ agree} = 45.5\%$). For example, eCLOSE1, "Provided relevant biology content" (Agree = 50%, Strongly Agree = 40%), eCLOSE16, "Helped me understand cancer processes," (Agree = 40%, Strongly Agree = 50%). No students strongly disagreed on either subscale, and only a small percentage disagreed with any of these items on both subscales ($M_{disagreeLabster} = 8.3\%$, $M_{disagreeeCLOSE} = 10\%$).

Motivation to Learn. Labster motivated students to learn biology and cancer content and work in the lab ($M_{agree} = 50\%$, $M_{strongly\ agree} = 36.1\%$). For example, Labster3, "Increased interest in biology content" (Agree = 50%, Strongly Agree = 41.7%) and Labster13, "Motivated me to pursue interest in in-person lab" (Agree = 33.3%, Strongly Agree = 41.7%). Results were similar for the eCLOSE program ($M_{agree} = 50\%$, $M_{strongly\ agree} = 33.33\%$). For example, students agreed that the program increased their interest in biology content (eCLOSE3 Agree = 50%, Strongly Agree = 30%) and motivated them to do in-person lab work (eCLOSE13 (Agree = 40%, Strongly Agree = 30%). No students strongly disagreed on either subscale, and only a small percentage dis-

Table 3. *Response Frequencies for the* *<u>Perception of Labster Program</u>* *by Subscale (n = 12).*

Subscale	Instrument Item	1 Strongly Disagree	2 Disagree	3 Undecided	4 Agree	5 Strongly Agree
Biology and Cancer Content Knowledge	1. Provided relevant biology content	0	0	1 8.3%	6 50.0%	5 41.7%
	2. Improved understanding of biology content	0	1 8.3%	0	9 75.0%	2 16.7%
	16. Helped me understand cancer processes	0	0	1 8.3%	8 66.7%	3 25.0%
	17. Helped me understand what I was learning connected to cancer	0	1 8.3%	1 8.3%	7 58.3%	3 25.0%
	Mean	0	8.3%	8.3%	62.5%	27.10%
Motivation to Learn	3. Increased interest in biology content	0	0	1 8.3%	6 50.0%	5 41.7%
	4. Motivated me to learn more biology	0	0	1 8.3%	8 66.7%	3 25.0%
	13. Motivated me to pursue interest in in-person lab	0	1 8.3%	2 16.7%	4 33.3%	5 41.7%
	Mean	0	8.30%	11.10%	50.0%	36.13%
Research Skills	5. Helped me understand what is done in a biology laboratory	0	0	0	8 66.7%	4 33.3%
	6. Helped me think like scientist	0	0	1 8.3%	8 66.7%	3 25.0%
	7. Helped me feel like scientist	0	2 16.7%	2 16.7%	5 41.7%	3 25.0%
	10. Improved my research skills	0	0	2 16.7%	7 58.3%	3 25.0%
	11. Improved my scientific thinking	0	0	2 16.7%	7 58.3%	3 25.0%
	12. Improved my critical thinking	0	0	2 16.7%	7 58.3%	3 25.0%
	Mean	0	16.7%	15.08%	58.34%	26.4%
Ease of Use	14. Prepared me for in-person laboratory experience	0	3 25%	2 16.7%	5 41.7%	2 16.7%
	15. Complemented other sessions	1 8.3%	0	1 8.3%	7 58.3%	2 16.7%
	23. Was easy to use	1 8.3%	2 16.7%	5 41.7%	2 16.7%	2 16.7%
	24. Worked well on computer	1 8.3%	1 8.3%	2 16.7%	5 41.7%	3 25.0%
	Mean	8.30%	16.7%	20.85%	39.6%	18.8%
Career Decisions	19. Motivated me to pursue a science career	0	0	2 16.7%	7 58.3%	3 25.0%
	20. Motivated me to learn about science careers	0	1 8.3%	1 8.3%	5 41.7%	5 41.7%
	21. Motivated me to pursue a cancer-related career	0	1 8.3%	2 16.7%	6 50.0%	3 25.0%
	22. Motivated me to learn about cancer-related careers	0	1 8.3%	1 8.3%	7 58.3%	3 25.0%
	Mean	0	8.30%	12.50%	52.1%	29.2%
Overall Experience	25. Indicate your overall experience	0	0	2 16.7%	7 58.3%	3 25.0%
	8. Provided a meaningful research experience	0	0	2 16.7%	9 75.0%	1 8.3%
	9. Felt like a research experience	1 8.3%	3 25.0%	1 8.3%	5 41.7%	2 16.7%
	18. Provided a valuable learning experience	0	1 8.3%	0	7 58.3%	4 33.3%
	Mean	8.3%	16.7%	13.9%	58.3%	20.8%

Table 4. *Response Frequencies for Perception of eCLOSE Program by Subscale (n = 10).*

Subscale	Instrument Item	1 Strongly Disagree	2 Disagree	3 Undecided	4 Agree	5 Strongly Agree
Biology and Cancer Content Knowledge	1. Provided relevant biology content	0	0	1 10.0%	5 50.0%	4 40.0%
	2. Improved understanding of biology content	0	1 10.0%	0	6 60.0%	3 30.0%
	16. Helped me understand cancer processes	0	0	1 10.0%	4 40.0%	5 50%
	17. Helped me understand what I was learning connected to cancer	0	0	1 10.0%	4 40.0%	5 50%
	Mean	0	10.0%	10.0%	47.50%	42.5%
Motivation to Learn	3. Increased interest in biology content	0	0	2 20.0%	5 50.0%	3 30.0%
	4. Motivated me to learn more biology	0	0	0	6 60.0%	4 40.0%
	13. Motivated me to pursue interest in in-person lab	0	1 10.0%	2 20.0%	4 40.0%	3 30.0%
	Mean	0	10.0%	20.0%	50%	33.3%
Research Skills	5. Helped me understand what is done in a biology laboratory	0	0	1 10.0%	6 60.0%	3 30.0%
	6. Helped me think like scientist	0	0	2 20.0%	3 30.0%	5 50.0%
	7. Helped me feel like scientist	0	0	2 20.0%	6 60.0%	2 20.0%
	10. Improved my research skills	0	1 10.0%	0	5 50.0%	4 40.0%
	11. Improved my scientific thinking	0	0	0	5 50.0%	5 50.0%
	12. Improved my critical thinking	0	1 10.0%	0	4 40.0%	5 50.0%
	Mean	0	10.0%	16.7%	48.3%	40.0%
Ease of Use	14. Prepared me for in-person laboratory experience	0	0	1 10.0%	7 70.0%	2 20.0%
	15. Complemented other sessions	1 10.0%	0	0	6 60.0%	3 30.0%
	Mean	10.0%	0	10.0%	65.0%	25.0%
Career Decision	19. Motivated me to pursue a science career	0	1 10.0%	1 10.0%	3 30.0%	5 50.0%
	20. Motivated me to learn about science careers	0	1 10.0%	0	4 40.0%	5 50.0%
	21. Motivated me to pursue a cancer-related career	0	0	3 30.0%	3 30.0%	4 40.0%
	22. Motivated me to learn about cancer-related careers	0	0	1 10.0%	5 50.0%	4 40.0%
	Mean	0	10.0%	16.7%	37.5%	45.0%
	23. Indicate your overall experience	0	0	1 10.0%	4 40.0%	5 50.0%
	8. Provided a meaningful research experience	0	1 10.0%	0	5 50.0%	4 40.0%
	9. Felt like a research experience	0	2 20.0%	0	5 50.0%	3 30.0%
	18. Provided a valuable learning experience	0	0	1 10.0%	2 20.0%	7 70.0%
	Mean	0	15.0%	10.0%	40.0%	47.5%

agreed with any of these items on both subscales subscales ($M_{disagreeLabster}$ = 8.3%, $M_{disagreeeCLOSE}$ = 10%).

Research Skills. Students agreed that Labster helped improve their *Research Skills* (M_{agree} = 58.3%, $M_{strongly\ agree}$ = 26.4%,). Items that were most important to the ACTION program were Labster5, "Helped me understand what is done in a biology laboratory" (Agree = 66.7%, Strongly Agree = 33.3%) and Labster6, "Helped me think like scientist" (Agree = 66.7%, Strongly Agree = 25.0%). Students had similar perceptions about eCLOSE (M_{agree} = 48.33%, $M_{strongly\ agree}$ = 40.0%,). For example, eCLOSE5, "Helped me understand what is done in a biology laboratory" (Agree = 60.0%, Strongly Agree = 30.0%) and eCLOSE6, "Helped me think like scientist" (Agree = 30.0%, Strongly Agree = 50.0%). However, more students thought the eCLOSE program made them feel like a scientist than the Labster program (Labster7: Agree = 41.7%, Strongly Agree = 25.0%; eCLOSE7: Agree = 60.0%, Strongly Agree = 20.0%). No students strongly disagreed on either subscale, and the percentage of students disagreeing with research skills items was higher for the Labster program than for the eCLOSE program ($M_{disagreeLabster}$ = 16.7%, $M_{disagreeeCLOSE}$ = 10%).

Ease of Use. The number of items on the *Labster Ease of Use Subscale* (I = 4) was higher than the eCLOSE subscale (I = 2) because the Labster simulations were self-contained online, whereas the eCLOSE program involved student interaction through Zoom. The Labster subscale asked students if Labster23 "Was easy to use" (Strongly Disagree = 8.30%, Disagree = 16.70%) and Labster24 "Worked well on my computer" (Strongly Disagree = 8.30%, Disagree = 8.30%). Labster23 was the only item which did not have a student positive response rate of 50% (Agree = 16.7%, Strongly Agree = 16.7%). In addition, there were items that asked if Labster prepared the students for an in-person laboratory experience (Labster14: Disagree = 25%, Neutral = 16.7%, Agree 41.7%, Strongly Agree = 16.7%), and if Labster complemented other sessions (Labster15: Strongly Disagree = 8.3%, Neutral = 8.3%, Agree 58.3%, Strongly Agree = 16.7%). When students were asked if eCLOSE prepared then for an in-person laboratory experience, they agreed at a higher level than their scores for Labster (Total positive Labster = 58.4%, Total positive eCLOSE = 90%). Students also mostly agreed that eCLOSE complemented other sessions (eCLOSE15: Strongly Disagree = 10%, Agree 60%, Strongly Agree = 30%), response rates that are higher than the Labster rates (Labster total agree = 75%, eCLOSE total agree = 90%).

Career Decisions. Two items that were especially relevant to the ACTION program were Labster19/eCLOSE19, "Motivated me to pursue a science career," and Labster21/eCLOSE21, "Motivated me to pursue a cancer-related career." Students agreed that the programs motivated them to pursue science careers (83% and 80% for Labster and eCLOSE, respectively) and cancer-related careers (75% and 70% for Labster and eCLOSE, respectively).

Overall Experience. Four items were related to the overall experience, including if the programs provided a valuable learning experience (Labster18/eCLOSE18) and a meaningful research experience (Labster8/eCLOSE8). Students agreed (agree and strongly agree) that both programs provided a valuable learning experience (91.6% and 90.0% for Labster and eCLOSE, respectively). In contrast, more students agreed (agree and strongly agree) that the eCLOSE program provided a meaningful research experience than Labster (83.3% and 90.0% for Labster and eCLOSE, respectively). When asked if they thought the programs felt like a research experience ((Labster9/eCLOSE9), 58.4% of students agreed that Labster felt like a research experience, whereas 80.0% of students felt that eCLOSE did. Additionally, 33.3% of students disagreed that Labster provided a meaningful research experience compared to 20% for eCLOSE.

A one-way repeated measures ANOVA was conducted on the raw score means of three eCLOSE and Labster *Perceptions of the Program Subscales* (*Biology and Cancer Content Knowledge*, *Research Skills*, and *Career Decisions*) to determine if there was a significant difference between the means; however, no significant differences were detected (See Tables 5 and 6).

Open-Ended Qualitative Data. Open-ended questions

Table 5. *Descriptive Statistics for Labster and eCLOSE Perceptions of Program by Subscale.*

Subscale	Instrument Item (Labster/ eCLOSE)	# Respondents (Labster/eCLOSE)	Labster Mean	Labster SD	eCLOSE Mean	eCLOSE SD
Biology and Cancer Content Knowledge	4	12/10	16.50	2.84	17.20	2.62
Motivation to Learn	3	12/10	12.80	1.48	12.40	1.84
Research Skills	6	12/10	24.6	3.17	25.5	4.06
Ease of Use Program	4/2	12/10	14.81	3.34	8.0	1.94
Career Decisions	4	12/10	16.20	3.05	16.90	3.28
Overall Impression	4	12/10	15.5	2.61	17.1	2.96

Table 6. *One-Way Repeated Measures ANOVA Results for eCLOSE/ Labster Perceptions of Program Subscales.*

Subscale	Source	Sum of Squares	df	Mean Squares	*F*	*p*
Biology and Cancer Content Knowledge	Factor	2.450	1	2.450	0.367	0.560
	Error	60.05	9	6.672		
Research Skills	Factor	4.050	1	4.050	0.321	0.585
	Error	113.450	9	12.606		
Career Decisions	Factor	2.450	1	2.450	0.355	0.566
	Error	62.050	9	6.894		

placed at the end of the *Perceptions of the Program Surveys* gave students opportunities to provide feedback about both virtual labs. Eleven students provided negative comments about the Labster program, which fell into three categories: 1) computer glitches, 2) lagging computers, and 3) difficulty understanding the simulations or instructions. Three students reported glitches during the Labster simulations, whereas three students reported lagging computer issues.

Four students complained of difficulty in understanding the Labster simulations or instructions. For example, "some parts of the simulation were not very well explained" and "There were a few instances where the program was difficult to understand, and it would take a long time to figure it out." These comments may be due to the content or reading levels of the simulations. It is important to note that six of the 11 simulations completed by the ACTION students were recommended for undergraduate students.

Only one response was received when students were asked to provide reasons for not completing all Labster simulations. The student commented on the time it took to complete each simulation due to navigating Labster, resulting in insufficient time to complete the simulations. When asked about their overall experience, general perceptions were positive. Students stated that Labster was "A good replacement since we couldn't be in person" and "Labster still could not completely mimic the opportunity of participating in real-life research labs." Finally, one student said, "The experience was very good considering the circumstances, but I would still love to be in a real lab."

Students provided 12 positive comments regarding the eCLOSE program and used adjectives such as immersive and engaging. One student noted the application of science in the eCLOSE experiments saying, "it was fun to actually use the stuff we have been learning about and see real results." Three students remarked about the nature of the lab experience with comments such as: "Using eCLOSE was a great way to learn what it is like in a lab setting" and "eCLOSE was a great opportunity that helped me get real life experiment experience despite not being able to get into labs." Finally, one student commented on the benefit of eCLOSE, which provided a more in-depth understanding of the topic: "Interesting topics which helped me understand cancer to a higher level."

Of the 11 negative comments provided by students, five mentioned the fast pace of instruction or instructors, and three three mentioned the lack of break time. Last, one student said, "Although eCLOSE was a great experience, it still could not fully replicate being in a real-life lab."

DISCUSSION

This study aimed to evaluate whether the two virtual labs would be an acceptable way to conduct ACTION instruction, especially during crisis events such as the COVID-19 pandemic. More specifically, it was to determine if they improved students' biology and cancer content knowledge, research skills, motivation to learn, and influenced students' career decisions. Data were collected from researcher-developed and distributed *Perceptions of the Program Surveys*, which were further subdivided into four subscales.

Results indicated that students perceived they learned biology and cancer content knowledge and improved their research skills. They also perceived that both programs were motivating and aided them in making career decisions. However, results indicated that students often had trouble with the Labster technology and instructions, which may be due to poor Internet conductivity issues in the rural region or the content and reading levels of the Labster simulations.

With the advancement of technology providing alternative approaches to instruction, knowing how and when to use virtual elements is vital. This study presented evidence that using two different virtual labs facilitated students learning when the virtual elements occupied less than 20% of total instructional time and supported physical, face-to-face activities. However, questions may still exist about virtual labs versus physical materials or in outreach settings, specifically the amount of time given to virtual activities in cancer-education programs. Klahr and colleagues (Klahr et al., 2007) posit that if children can learn as well with virtual as with physical materials, then the practical advantages of virtual materials may make them the preferred instructional medium in many contexts. Additionally, Zacharia and Constantinou (Zacharia and Constantinou, 2008) question the assumptions about physics lab work and call for a redefinition and restructuring of experimentation to include physical and virtual manipulatives. Their call to include both physical and virtual materials was precisely the strategy enacted by the ACTION leadership when the COVID-19 pandemic threatened their cancer-related summer program.

These findings apply to outreach programs that do and do not use virtual laboratories. For example, Farrell et al. (Farrell et al., 2021) described the attempts of their STEM outreach program team to alter their *All About Arsenic* project in the face of COVID-19 challenges. As teachers and students moved to online teaching and learning in the spring of 2020, researchers scrambled to adjust their programs. The team developed multiple strategies to keep the project functioning smoothly. Although they did not mention virtual labs, they implemented other changes, such as adding new project elements, adapting existing elements, moving training sessions online, creating a curriculum development module, and developing alternatives to public meetings for community outreach. Had the team been aware of the success of other programs in implementing virtual labs, *All About Arsenic* may have taken advantage of this option as well.

This study contributes significantly to a unique segment of the literature on the use of virtual laboratories in cancer-related outreach programs. Studies comparing virtual and traditional instruction have been conducted at the university level in physics (Darrah et al., 2014; Viegas et al., 2018), elementary school-aged children in physical science classrooms (Furió et al., 2015), middle school-aged children with inquiry-based activities (Klahr et al., 2007), the research community (S. Ray et al., 2012), and university environmental science students (Paul and Jefferson, 2019). However, less is known about virtual labs in cancer-education outreach programs. While a portion of the ACTION programming was dedicated to virtual activities, most of the program remained face-to-face to maintain vital connections with students. Questions may still exist about the optimal percentage of instructional time educators should devote to virtual activities at the risk of losing face-to-face interactions. As one of the ACTION participants commented, “The experience was very good considering the circumstances, but I would still love to be in a real lab.”

Program directors considering the use of virtual laboratories in their outreach program should develop criteria for selection and carefully vet their final choices. ACTION program leadership looked for inexpensive programs that could easily be accessed in a rural region with known Internet connectivity limitations. In addition, they wanted a program with content relevant to the ACTION program, accessible to Appalachian students, and organized in short units that could be completed in hour-long segments. Last, they wanted units that included content assessments, graphical models of actual experiments, and engaging research questions. Results show that the most significant barriers to implementation were Internet conductivity, website navigation problems, and students’ problems with the pace of instruction. Carefully matching the virtual laboratory’s technology demands with students’ needs may alleviate some of these issues. In the future, if the program uses virtual laboratories, the ACTION program director hopes to use them while students are at UK, thereby alleviating Internet connectivity limitations. Furthermore, matching the cognitive demand of the virtual labs, especially the reading and content levels, might assist students in their development of conceptual understanding.

Limitations. Every study and program are limited by its design, funding, time commitments, and this study is no different. First, the small sample sizes should be recognized. While this study’s findings provide insight into the benefits of virtual labs, its findings are limited due to small sample sizes and even fewer responses to some subscales. The ACTION program itself is limited to small cohorts because of funding limitations and so each student can receive individualized mentoring and research opportunities. However, smaller sample sizes increase the chance of assuming as true a false premise, and smaller sample sizes provide challenges when drawing accurate conclusions about a larger population. Second, this study used students’ self-reported questionnaires as the primary data source. Self-report data carries risks based on variable respondent knowledge, comprehension, and interpretation of scale items. Last, 2021 was the first year the ACTION program used virtual labs and collected data on its use; therefore, it has no comparison group. The ACTION leadership team is considering using virtual labs in other ways in the future, which will serve as a comparison to the data collected for this study.

Future Research. The overarching goal of the ACTION program is to provide cancer education and training for future career professionals in Appalachian Kentucky. This goal has been admirably achieved since the program’s inception; however, the ACTION leadership team could better support their findings with improvements in its evaluation design. For example, in the context of this study, high-quality instruments measuring gains in biology and cancer knowledge could be developed and used in a pre-test/post-test design for both virtual labs. In addition, control groups could be incorporated into the study to look at the effectiveness of the virtual laboratories. Students were online for approximately 20% of their programming time in this cancer-education program. Because the question of how much time should be used in online applications is extant in the literature, future ACTION programming might alter that percentage to determine if the amount of time of virtual labs alters students’ perceptions.

CONCLUSION

ACTION is a comprehensive cancer-education program that does commendable work with underserved students in Appalachian Kentucky. Incorporating virtual laboratories into the ACTION programming during the COVID-19 pandemic was a sound instructional choice for the students. The evidence provided herein should give other researchers and outreach program developers the necessary information to consider selecting virtual lab vendors and using virtual labs in their programs.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this the manuscript.

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ABBREVIATIONS

ACTION: Appalachian Career Training in Oncology Program; ARC: Appalachian Regional Commission; CTT: Classical Test Theory; MCC: Markey Cancer Center; UK: University of Kentucky

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