Building Engineers' Global Competency Via Lab-Kit-Based Virtual Exchange

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Abstract

Virtual exchange (VE) is an educational collaboration between international partner institutions that facilitates global perspectives among students. Although VE is becoming more common in higher education across disciplines, it is unusual to find a VE embedded in engineering courses, particularly required courses. A primary obstacle to implementing engineering VEs is that many required engineering courses utilize hands-on, lab-based learning that is difficult to translate into remote collaboration. A novel solution is mailing physical artifacts between institutions, allowing all students to interact with the same educational hardware whilst communicating virtually. A five-week VE collaboration between the University of Florida (UF) in the United States and Aswan University (ASWU) in Egypt was executed within Fluid Mechanics (EGN 3353C), a required undergraduate lab course within UF's Mechanical and Aerospace Engineering Department. The VE implements fully-contained, desktop-scale lab kits capable of running 12 unique experiments that demonstrate energy and fluids principles with the fidelity of traditional brick-and-mortar laboratory equipment. 140 lab kits were designed and manufactured at UF, and 18 kits were shipped to ASWU. Students at UF and ASWU collaborated to conduct experiments, evaluate data, and report the results. This paper reports the effectiveness of lab-kit-based VE within a required engineering course to increase international competency of undergraduate mechanical and aerospace engineering students based in the United States. Results are quantified through the International Critical Thinking and International Communication Attitudes and Beliefs Survey, a Likert scale survey instrument developed by UF. The survey was administered to 114 UF students enrolled in EGN3353C prior to and following the VE interaction. Using two-tailed Wilcoxon signed rank testing, survey responses from before and after the VE were evaluated for significant statistical change. Of the 26 survey questions, 4 showed statistically significant change. Results indicate that although there were positive outcomes to this VE implementation, future work can be done to make it more effective.

Introduction

The University of Florida (UF) located in Gainesville, Florida, United States, and Aswan University (ASWU) located in Aswan, Egypt partnered for four long semesters to deliver a Virtual Exchange focused on teaching principles of fluid mechanics via hands-on, lab-based learning. Virtual Exchange (VE) is an educational collaboration between international partners. It can take various forms, spanning from one week to an entire semester of interaction. VE activities can include virtual guest speakers, student-student discussions, assignments that connect students from different institutions, collaborative projects, or complete courses taught in tandem by faculty from partnering institutions **[1]**.

The participants of the United States-Egypt VE were undergraduate engineering students enrolled at UF or ASWU. The program was funded by the U.S. Department of State through the Stevens Initiative with the goal of increasing international skills and cultural competency of participants. In alignment with this goal, the original plan for the program was to maximize student exposure to an international opportunity by implementing the VE within the curriculum of a pre-existing undergraduate Fluid Mechanics course in UF's Mechanical and Aerospace

Engineering Department and within an equivalent course at ASWU. However, due to institutional obstacles, the VE was instead implemented during the first semester (Fall 2024) into a low-enrollment technical elective, and during the second semester (Spring 2025) it was delivered as an extracurricular extra credit opportunity across four required mechanical engineering courses. Finally, in the third semester (Fall 2025) of the program, VE was introduced into Fluid Mechanics (EGN 3353C), which is a required class for students in UF's mechanical or aerospace engineering program. In the fourth semester (Spring 2026), the last offering of the VE within the grant performance period, the program is again being run in Fluid Mechanics (EGN 3353C). However, since this final implementation is ongoing at time of writing this manuscript, its results will be reported in a follow-on publication.

The keystone characteristic of this VE is the use of desk-scale lab kits, identical between UF and ASWU, that allows students at both institutions to synchronously perform experiments, collect and analyze data, and work together on written and verbal presentations.

Background & Theory

In the increasingly globalized world, VE programs are beneficial for providing students with an accessible path to developing cultural awareness, providing an economic and flexible alternative to study abroad, and re-contextualizing course content through diverse perspectives. Additionally, VE can build digital literacy, introduce students to experts from across the world, and strengthen networks between international institutions. Students seeking employment or graduate programs overseas can gain important experience, resources, and opportunities for their professional development through VE **[1]**. For these reasons, as well as increased availability of resource guides for educators, VE is gaining popularity in higher education. For example, the number of University of Florida students participating in VE programs increased from zero to 39,000 from the 2017-2018 academic year to 2024-2025 academic year **[1]**.

Engineering students in particular have the potential to benefit from VE. A 2021 UF survey of undergraduates indicated that engineering students possess the rate lowest among majors at the university in skills related to intercultural competency and global awareness **[2]**. Cultural attitudes discourage both faculty and students from seeking international experiences. A 2014 study by Cech found that students' beliefs in the importance of public welfare decreases over the course of their engineering education. Many engineering education environments encourage the cognitive separation of "technical" and "social" competencies and devalue the latter. Concern for the societal impacts of engineering technologies may be framed as "irrelevant to 'real' (technical) considerations" **[3]**.

However, despite the apparent potential for engineering students to benefit from VE, these programs are less prominent in engineering disciplines than elsewhere in academia. For example, most students who participated in VE programs in 2024-2025 at the University of Florida (UF) belonged to the Colleges of Business and Liberal Arts and Sciences. In 2024-2025, 20.5% of College of Business students participated in a VE, whereas only 0.8% of College of Engineering students participated **[4] [5]**.

There are many challenges associated with implementing a successful VE program. Common obstacles include difficulty finding and maintaining international partners, technology barriers or curriculum misalignment between partnering institutions, cultural misunderstandings, and lack of instructor training **[6]**. In addition to these general challenges, engineering programs experience unique obstacles that may further contribute to the lack of VE projects implemented in engineering programs as compared to other disciplines.

A cultural attitude that discourages engineers from thinking about public or global implications of their work **[3]** also minimizes and undermines the potential benefits of VE programs: better international competency, greater cultural flexibility, and the ability to view technical topics from different perspectives. Thus, the reason that engineering students may benefit from VE is the same reason why they may choose not to engage with these programs. Engineering students may feel unmotivated to engage with VE if they do not understand the relationship between the VE and their engineering degree **[7]**. To many students and even faculty, the link between VE and engineering is less clear than between VE and other educational disciplines such as language or public health. Due to the spartan number of existing examples, there are limited opportunities to challenge and rebut engineering students' and faculty misconceptions about the relevance of VE projects to their course content.

There is another major challenge that engineering programs face in VE implementation: many engineering courses utilize hands-on, pragmatic learning that can be difficult to translate into virtual mediums. Moreover, the emphasis on experiential, hands-on learning in engineering has accelerated over the past 20 years since ABET began emphasizing its importance for accreditation in the early 2000's. Over the past 20 years, most established engineering programs have come to rely on brick-and-mortar laboratory setups to run educational experiments, and this investment dissuades engineering departments from offering online course options. If a US institution and its international partner have unequal or different access to resources, as is often the case, it may be impossible for students at the partner institution to gain access to equivalent equipment for experiment-based collaboration **[6]**. As a result, hands-on learning within VE requires more creative solutions. These solutions can include use of available materials to build analogous experiments at each institution, exchange of digital files, use of computer simulations, and use of virtual reality **[8] [9]**.

A previously unexplored solution is the use of lab kits. A lab kit is a packaged set of laboratory equipment that allows students to build experiments and collect data with the same fidelity as brick-and-mortar lab set ups. Hands on kits have been deployed successfully for in-person, hybrid, and remote engineering instruction **[10] [11] [12] [13] [14] [15] [16]**. They are low-cost and can be packaged for easy transport, so they could be shipped internationally from one institution to another, allowing all students access to identical hardware, even in the face of resource disparity. They provide important technical context that makes the VE feel relevant to engineering students who may otherwise feel discouraged from engaging.

Methods - Pedagogy

The fluids lab kits that anchored this VE were designed and manufactured by UF in consultation with ASWU **[10] [11]**. Eighteen kits were packaged and shipped to ASWU. Each lab kit, consisting of 38 unique parts and 61 total parts, is contained inside a 41-quart Rubbermaid clear storage container (Fig. 1-2). Ten unique thermal-fluids experiments can be built from these parts. Since the UF-ASWU VE occurred over just 5 weeks, only 3 of the experiments were used for these interactions. The experiments used in this VE were 1) Hydrostatic Standpipe, 2) Pump Curve, and 3) Torricelli Fountain.

Fig. 1 Lab kits ready for distribution.

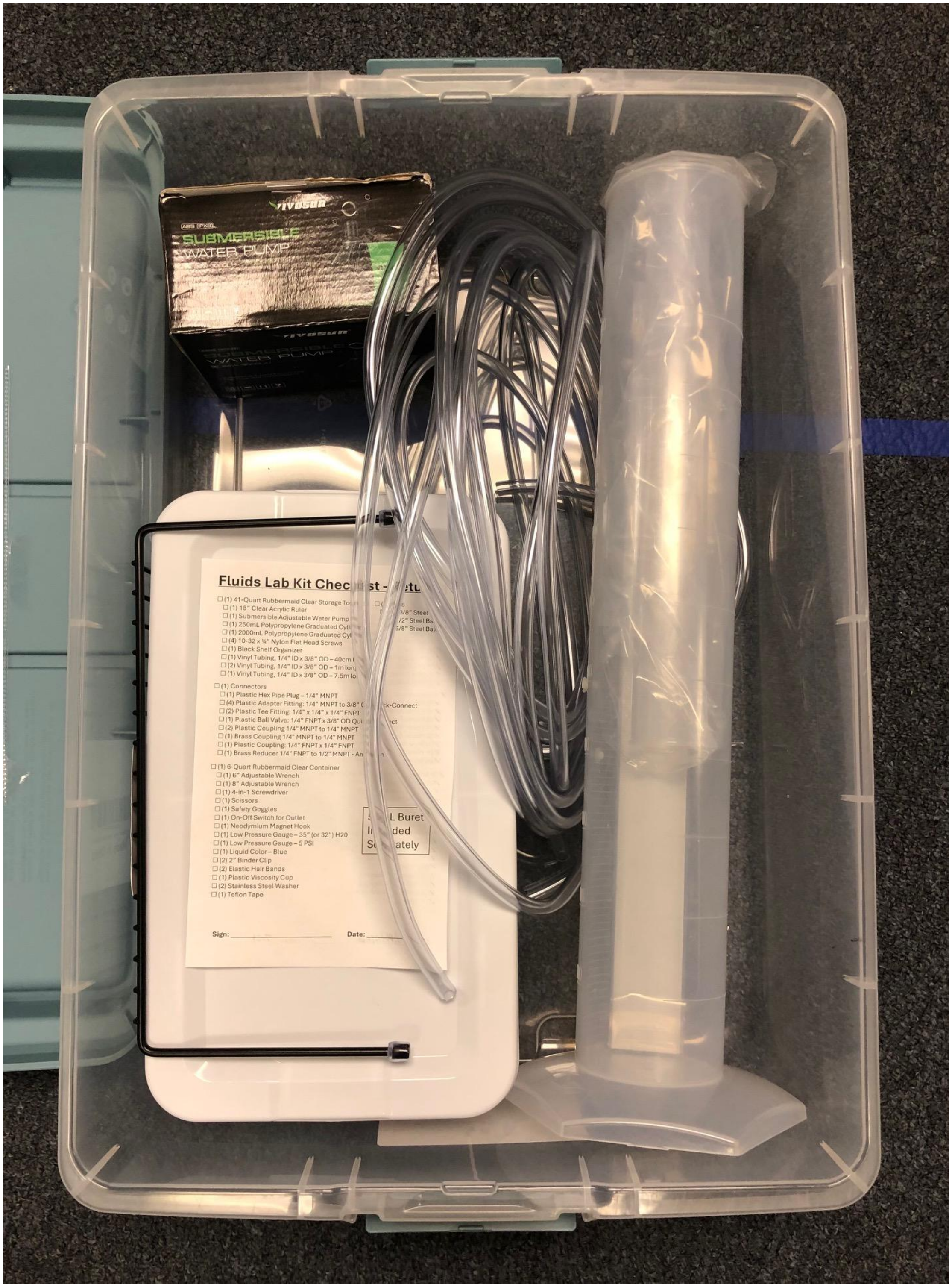

Fig. 2 Inside of a lab kit.

The VE was embedded in the UF course EGN3353C: "Fluid Mechanics with Lab (Egypt Virtual Exchange)" and an equivalent ASWU course. EGN3353C is a required course for the UF bachelor's degree in mechanical engineering. The number of participants was 113 UF undergraduate engineering students, 1 UF criminology student, and 32 ASWU students. Each UF student was given a lab kit for individual use; ASWU students shared lab kits stored in their classroom.

The program took place over five weeks, with synchronous meetings occurring for 50-minutes once per week. The first week consisted of program introductions and a self-introduction activity using Padlet. During the second week, students were organized into four groups of 3-4 individuals, each group being a combination of American and Egyptian students. Once set, these groups were maintained for the duration of the program. In their groups, students again used Padlet to share research about hydroelectric dams around the world. During the synchronous class meeting, students performed the Hydrostatic Standpipe experiment using their lab kits. Asynchronously, students were assigned group written lab reports to synthesize the results of the experiment. Over the following three weeks, students performed the Pump Curve and Torricelli Fountain experiments and collaborated on group video lab reports.

Methods - Evaluation

In order to evaluate effectiveness of the VE program relative to international and intercultural skills, the "International Critical Thinking (IntCRIT) and International Communication (IntCOMM) Attitudes and Beliefs Survey" was used, abbreviated to IntCRIT and IntCOMM **[12]**.

This survey tool was developed by the University of Florida during an initiative to increase international educational offerings. The survey takes approximately five minutes to complete and contains eight demographic questions and 26 5-point Likert-scale questions with responses ranging from "Strongly Disagree" (rated “1” on the scale) to "Strongly Agree" (rated “5” on the scale). The questions center around two student learning outcomes: critical thinking and communication. In this context, critical thinking is defined as the ability to interpret global and intercultural issues using judgment, analysis, reasoning, and solution finding. Communication is defined as the ability to effectively interact with members of another culture using sensitivity, production, awareness, adaptability, and acceptance **[12]**. The full list of items is tabulated in the Appendix.

The IntCRIT and IntCOMM surveys were presented to UF students as one combined survey distributed via email. Each UF student was administered the survey twice, once before the VE began and once in the final week of the VE.

The surveys were administered to 114 UF students. Of the 114 participants, $N = 71$ responded to both the pre-VE and post-VE survey. These responses enabled the use of a two-tailed Wilcoxon Signed Rank Test to evaluate changes between survey results. Two-tailed testing was selected over one-tailed tests to account for the possibility that the VE intervention resulted in a reduction in student international competence or confidence.

Results

Of the 114 UF participants, $N = 71$ responded to both the pre-VE and post-VE survey. Figure 3 and 4 gives a non-statistical visualization of the average responses to the IntCRIT and IntCOMM surveys respectively. The blue/circle markers represent average responses for the class prior to VE participation, and purple/triangle markers represent average responses for the class after VE participation.

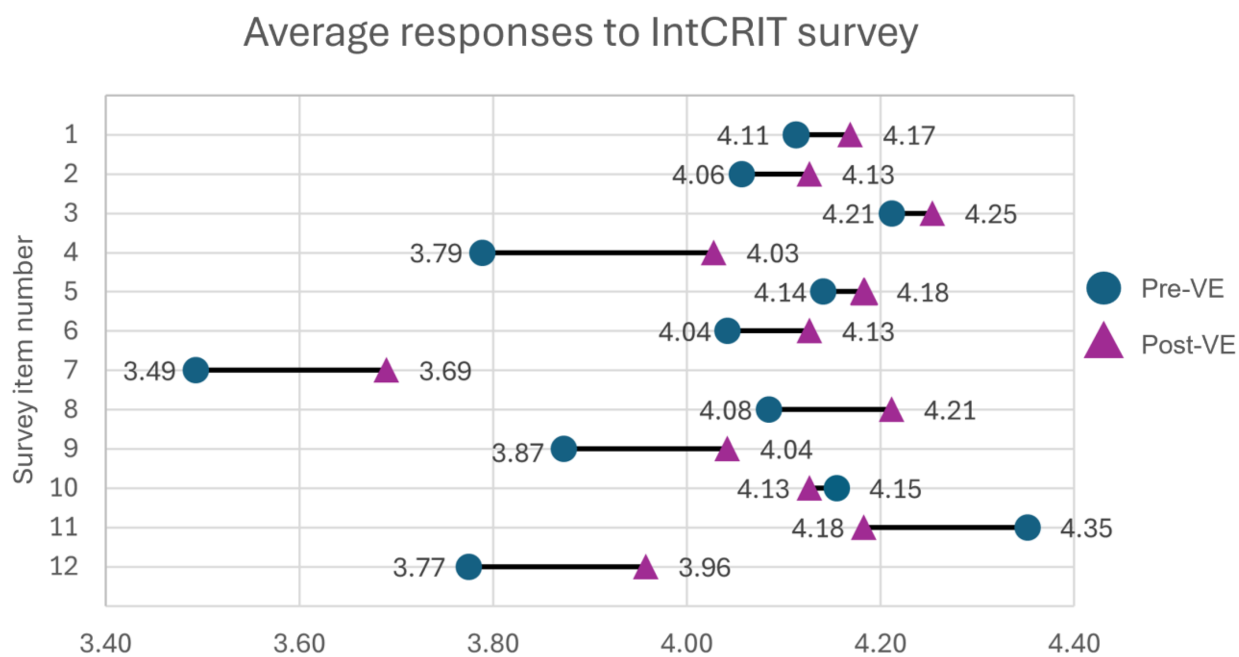

Fig. 3 Average responses to IntCRIT survey; blue/circle markers indicate pre-VE responses and purple/triangle markers indicate post-VE responses.

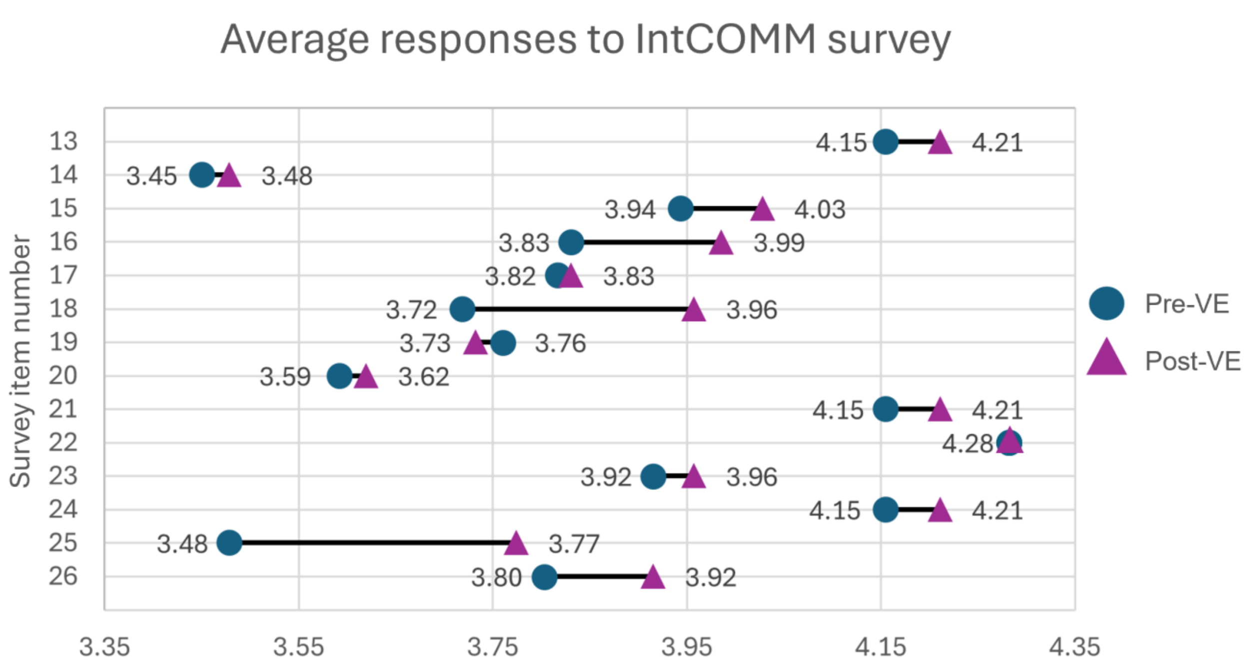

Fig. 4 Average responses to IntCOMM survey; blue/circle markers indicate pre-VE responses and purple/triangle markers indicate post-VE responses.

The Wilcoxon Signed-Ranked test is a nonparametric test for paired samples; it is appropriate for cases in which normal distribution cannot be assumed. The test compares the probability that a random value from the first sample is greater than its paired value in the second sample. As is standard, a significance level of $P < 0.05$ is used as a threshold for statistical significance. Of the 26 items, four items produced statistically significant differences between pre- and post-VE responses.

Items 4, 11, 18, and 25 saw statistically significant differences between pre- and post-VE responses, with $P < 0.05$. These items were:

Q4. "I can make effective decisions when placed in different cultural situations." ($P = 0.011$)

Q11. "Knowing about other cultural beliefs is important." ($P = 0.015$)

Q18. "I feel comfortable in conversations that may involve cultural differences." ($P = 0.016$)

Q25. "I feel comfortable discussing international issues." ($P = 0.007$)

Responses to Items 4, 18, and 25 changed in the positive direction, meaning that respondents indicated more agreement with the statement after the VE compared to before. However, Item 11 changed in the negative direction, meaning that respondents agreed less with the statement after VE participation. A visual representation of positive and negative change can be seen in Figures 3 and 4. The other 22 survey items did not result in statistically significant change.

Discussion

There are several possible reasons why most of the survey items were not affected. Firstly, this was a short-term program that took place over only five weeks, with only 250 minutes of scheduled synchronous interaction between UF and ASWU students. Program facilitators observed that although ASWU student attendance was high during these sessions, UF student attendance was low. The intention of the group written and video assignments was to encourage further out-of-class interaction between institutions. However, many UF students reported throughout the program that ASWU students were unresponsive to communication attempts or did not participate in these assignments. For example, it was recommended that students coordinate a synchronous meeting with their groups to record video lab report presentations; despite all groups including both American and Egyptian students, most of the assignment submissions only included American students in the videos, because American students were unable to get into contact with their international counterparts. Therefore, the amount of meaningful contact between UF and ASWU students was low.

Although the lab kits might have helped close the gap between VE and hands-on engineering learning, this program still faced many obstacles common to VE across any discipline. These obstacles may have reduced the overall effectiveness of the program. The primary challenge, as previously mentioned, was communication. Even when synchronous interaction between students was achieved, language barriers made it difficult for students to effectively communicate with each other; although English is the official teaching language of ASWU, many of the students are more comfortable in Arabic. Other obstacles included differences in technology. UF students communicate primarily through Microsoft Teams and Canvas, whereas ASWU students do not typically use these platforms. ASWU students and faculty preferred cell-phone-based communication platforms, including WhatsApp. Unfamiliarity with the US-preferred technology platforms may have contributed to lapses in ASWU student participation. Lastly, UF course restraints may have contributed to the effectiveness of the VE. The motivation behind embedding the VE into a required course was to increase enrollment and to encourage international interaction among students who may not choose to interface with such opportunities unless it was required for degree completion. Although this implementation of the VE did result in a high UF enrollment compared to previous semesters, it also resulted in a larger student-to-faculty ratio which made it difficult for faculty to provide personal feedback to students or to help them manage problems. Another drawback of embedding VE in a required course is that there is already a challenging curriculum outside of the VE program in the course; in addition to the VE content, students also had lectures, homework, quizzes, and exams. It is possible that the other course requirements detracted from the time and energy students were able to dedicate to the VE interactions. Students may have felt less motivated to develop creative solutions to VE challenges because they were focused on other essential elements of the course. A lack of time and motivation would make it difficult to overcome challenges and thus could make the VE less effective.

Although the statistical results of the surveys are lukewarm, qualitative feedback indicates positive outcomes. UF students who attended the synchronous class sessions expressed that they found the sessions interesting and helpful. They enjoyed the experience of watching the ASWU students conduct experiments over Zoom, and they found the live sessions helpful for troubleshooting their own experimental set ups. Without the VE, the Fluid Mechanics course would not have included any lab-based components; it would have been entirely theoretical. Students expressed that the lab kits helped them better conceptualize lecture content.

On the ASWU side, faculty reported many positive outcomes for their students. Prior to the UF-ASWU collaboration, VE had been largely unheard of at ASWU. From an intercultural competency standpoint, faculty report that the VE gave their students the opportunity to practice speaking English with native speakers, build friendships and academic relationships, and learn how to engage respectfully with people from other cultures. The VE has inspired some of their students to seek continued global experiences with the United States and other countries. The faculty said that the lab kits in particular were extremely impactful for their students' learning experience. They discovered that it was possible to use simple, inexpensive tools to convey the scientific topics that overwise would have been purely theoretical. Similarly to UF, this course would not have contained any hands-on learning without the VE. However, unlike UF which has other lab-based courses in the mechanical engineering degree progression, ASWU students receive limited or no practical exposure at all throughout their undergraduate degree. Therefore, the impact of the lab kits cannot be understated. The lab kits allowed the students to conduct experiments themselves, overcome mistakes and challenges, calculate results, and discuss them with UF counterparts. Lastly, the faculty describe the impact the program had on student self-confidence, both technically and socially. From a technical perspective, it gave the students confidence when they conducted experiments alongside American students and achieved the same results; it made the students feel proud of their Egyptian education and confident that they could perform on par with foreign students. From a social perspective, the VE gave ASWU students more confidence conversing in English and understanding that mistakes are part of the learning process. According to one faculty member, “Virtual exchange broke the barrier of fear, giving them courage to interact with others.” Now, students are comfortable pursuing other international opportunities. Although it is too early to assess the outcomes on career or graduate studies, faculty say that the skills their students developed in the VE, as well as the VE completion certificate on their resume, will give them a competitive advantage in the future.

Conclusion

The University of Florida (USA) and Aswan University (Egypt) collaborated on a Virtual Exchange that leveraged desk-scale, portable lab kits to teach Fluid Mechanics. The five-week VE was embedded into a UF undergraduate mechanical engineering course Fluid Mechanics (EGN 3353C). UF participants were administered the International Critical Thinking (IntCRIT) and International Communication (IntCOMM) Attitudes and Beliefs Survey before and after their participation in the VE. $N = 71$ participants responded to both surveys. Two-tail Wilcoxon Signed-Rank test indicated a statistically significant change in pre/post-VE survey responses for four of the survey items; of these items, three increased in the positive direction and one in the negative direction. Qualitative feedback on student experience from both UF and ASWU indicate positive outcomes of VE participation and lab kit use, including greater understanding of theoretical concepts, development of international skills, increased self-confidence, and professional development. The limited statistical impact of the program could be the result of various challenges faced during implementation, such as communication issues, attendance, and course restrictions.

Virtual exchange is a promising pathway for both intercultural and subject-matter teaching. The lab kits gave students from both universities a hands-on, pragmatic learning opportunity that they would not have had otherwise. It also served as a bridge between students from different cultures and languages. Future work should be done on refining VE implementation strategies, including tackling challenges that may have retracted from the effectiveness of this particular implementation. In future implementations, a survey could be conducted of both UF and ASWU students. More open-ended questioning would also be useful as opposed to just a Likert-scale survey. Additionally, research might be conducted on the impact of the VE on technical course learning outcomes in addition to international competency skills. Currently, research is being conducted to expand the lab kit experiment roster, particularly to include a Hydroelectric experiment with relevance to ASWU’s relationship to the Aswan High Dam [13].

Acknowledgments

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Appendix

Table 1: IntCRIT & IntCOMM Survey Items

Item	Description	Component

1	I consider different perspectives before making conclusions about the world.	Analysis
2	I am able to manage when faced with multiple cultural perspectives.	Solution Finding
3	I am open to different cultural ways of thinking in any international context.	Judgement
4	I can make effective decisions when placed in different cultural situations.	Reasoning
5	Knowing about other cultural norms and beliefs is important to me.	Judgement
6	I am able to think critically to interpret global and intercultural issues.	Analysis
7	I actively learn about different cultural norms.	Solution Finding
8	Understanding different points of view is a priority to me.	Judgement
9	I can recognize how different cultures solve problems.	Reasoning
10	I can contrast important aspects of different cultures with my own.	Judgement
11	Knowing about other cultural beliefs is important.	Judgement
12	I am able to recognize how members of other cultures make decisions.	Analysis
13	I demonstrate flexibility when interacting with members of other cultures.	Adaptability
14	I prefer to socialize with people of my culture.	Adaptability
15	I am confident that I can adapt to different cultural environments.	Production
16	I am able to communicate effectively with members of other cultures.	Production
17	I like working in groups with students from other countries.	Acceptance
18	I feel comfortable in conversations that may involve cultural differences.	Sensitivity
19	When working on a group project, I enjoy collaborating with students from other countries.	Acceptance
20	I often ask questions about culture to members of other cultures.	Awareness
21	I enjoy learning about other cultures.	Awareness
22	I appreciate members of other cultures teaching me about their culture.	Sensitivity
23	I am able to interact effectively with members of other cultures.	Production
24	I appreciate differences between cultures.	Acceptance
25	I feel comfortable discussing international	Adaptability

	issues.	
26	I can clearly articulate my point of view to members of other cultures.	Production