ONE STEP AT A TIME: DEEPENING SOCIO-TECHNICAL LEARNING IN UNDERGRADUATE ICT EXTERNSHIPS TO BRIDGE THE DIGITAL DIVIDE

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ABSTRACT

This paper describes the temporal progression of human and social dimensions that undergraduate information and communications technology (ICT) students realized during an experiential learning externship where they explored digital divide technology solutions for low-income neighborhoods in the surrounding urban community. The described research represents significant adaptation and use of socio-technical integration research (STIR) with undergraduate ICT students engaged in work based experiential learning to promote equity in STEM education, instill a sense of civic responsibility, and practice approaches to tackling complex societal problems. Methods used for the research study included: STIR, semi-structured interviews, and on-site group observations. Using STIR, an embedded social scientist conducted regular one-on-one dialogs with three of four student externs, to collaboratively describe each student's consideration of human and social dimensions as part of their technical work, explore alternative choices and their potential outcomes, and engage in reflexive learning that in some cases, influenced deliberate changes to material and behavioral practices. The on-site observation of group activities within the ICT innovation center situated in the local urban community provided additional ecosystem context during technical solution design and development of the digital divide solution for local high schools and feeder schools. Outcomes for participating undergraduate ICT students showed: 1) Technology learning improvements for all students; 2) Capacity building to reflect, anticipate and respond to sociotechnical interactions for some students; and 3) Each student was able to progress to a new level of socio-technical learning and decision making. Reflexive discourse with participants surfaced cultural assets and consideration of alternative knowledges in collaborative technology design, development, and implementation that can potentially lead to solutions that are more community centered now and in the future as the ICT students transition to the workforce.

KEYWORDS

Digital Divide; Socio-technical Integration; Experiential Learning

1. INTRODUCTION

This pilot research study examined the application of ICT in low-income urban neighborhoods where residents face inequities in access to education, broadband, and computing resources. The study engaged STEM undergraduate externs who were students of color as contributors to the digital divide ICT solutions for the neighboring community. Additionally, two of the externs had personally experienced the global digital divide in underdeveloped regions of Africa before coming to the United States. This study advances the state of the art in Socio-Technical Integration Research (STIR) by applying the method to undergraduate student projects and by theorizing the results in terms of socio-technical learning. The study developed students' socio-technical learning by deepening their reflexiveness about their life worlds and career trajectories and increasing their future-making agency and sense of civic responsibility. Socio-technical learning combines three analytically distinct steps: learning technical skills, e.g., configuring citizen's band radio services and devices; learning to reason about the societal context of technology decisions, e.g., the need to translate device instructions to Spanish; and applying social and technical learning together in the context of actual decision making, e.g., how socioeconomics of neighborhoods and housing structures impact device selection and placement. While these steps are iterative in practice, the process of acquiring the corresponding skills appears to proceed sequentially. Engaging students in socio-technical learning expands current work-based experiential learning beyond the typical agenda to develop a technically skilled workforce (Gage, 2018; Benbow and Hora, 2018; Schonell and Macklin, 2019; Board on Higher Education and Workforce et al., 2016).

This research also contributed new knowledge to the STIR application portfolio, in the form of a case study that explores a new target audience, their innovation and learning processes, and the setting in which they innovate. In contrast to prior studies that explored use of Responsible Innovation principles in educational settings to train pre-service teachers (Richter et al., 2019) and STIR focus group discussions with undergraduate students about `what-if' scenarios (Lukovics et al., 2019), this study adjusted the STIR protocol to engage with STEM students at 2-year colleges while they actively participated in work-based experience projects in an open lab-like environment. The study found that socio-technical learning happens one step at a time, as the externs successively built on existing skills and acquired new ones, even when they began at different levels of learning. Based on what was learned from this pilot study, refinements to STIR will be developed for use in similar contexts and disseminated to other 2-year colleges that are Hispanic Serving Institutions, enrolling at least 25% full time equivalent Hispanic Students.

The broader public impacts are two-fold. First, by enabling students to see into future imaginaries and recognize themselves as world builders and agents for positive social change, the research has the potential to broaden participation in STEM by increasing engagement, retention, and graduation of underrepresented minorities in Information Technology (IT) programs. Depending on perceived value by students, faculty, industry mentors, and customers, optimizations to the pilot study will be tested at up to four additional sites as future research studies. Further research will explore the potential to embed findings within instructors' pedagogical strategies and student / community partner journaling as self-service mechanisms to build agency and scale implementation.

Second, in building responsible innovation capacity, the research also contributes to new approaches for community centered solutions that leverage cultural assets of underrepresented students and consider alternative knowledges in collaborative technology design, development, and implementation. As students graduate and enter the workforce, they carry with them the capacity to respond to societal dimensions of technology in daily work practices and processes.

The remaining structure for this paper includes seven sections. Sections 2 and 3 describe the problem scenario and the undergraduate experiential learning contexts. Section 4 introduces STIR, why it was used in this study, and how prior STIR studies informed this work. Details for the data collection and results are covered in Section 5 and discussed in Section 6. Section 7 describes the conclusion.

2. DIGITAL DIVIDE IMPACTS TO EDUCATION IN PHOENIX

In education, the digital divide has been present since the mid-1980's revealing disparities between schools that had funding available to invest in technology and others that did not. More broadly, the digital divide has taken on multiple meanings, from infrastructure, devices, and internet services to digital literacy and social learning (van Deursen and van Dijk, 2020). In Phoenix, the digital divide is present in various facets. According to the U.S. Census Bureau (U.S. Census Bureau, 2019), within the neighborhoods served by the Phoenix Union High School District, 20.1% of households are without an internet subscription, and for households that do have an internet subscription, 17% only have a cellular internet connection. While 94.6% of households have computing devices in the home, for 18.8%, the smartphone is the only computing device.

When the pandemic shut down schools in March 2020, students across the region did not have the necessary reliable high-speed internet service or sufficient devices to continue learning at home. Schools distributed thousands of devices and hotspots to students who had need to enable a rapid transition from school to home learning. Strategies included: setting up temporary hotspots; mapping community Wi-Fi points; and equipping buses with Wi-Fi to help fill short-term needs. It immediately became evident that a long-term solution to bridge the digital divide for education was needed. Over eighteen months, the City of Phoenix, Phoenix College, the Phoenix Union High School District (PXU), Alhambra and Cartwright Elementary Districts, and other PXU feeder districts partnered to design, fund, and develop a long-term platform solution leveraging new and existing infrastructure that went live over a four-square-mile pilot proof of concept (POC) area in September 2021. The POC created a canopy of wireless coverage to reach students' households by leveraging the schools' physical locations as installation points. When fully implemented, the Phoenix Digital Education Connection Canopy (PHX DECC) will provide broadband direct-to-school internet access for 250 thousand families in the surrounding community. The PHX DECC is a replicable and sustainable educational network for connecting students to schoolwork and virtual classrooms in Phoenix, Arizona, and beyond.

3. UNDERGRADUATE ICT STUDENTS' EXPERIENTIAL LEARNING

In the future, Phoenix College will create a program that trains technology students to install, maintain and operate PHX DECC, which can help them find jobs with schools locally, or anywhere the technology will be installed. In the summer and fall of 2021, early adopter undergraduates in ICT programs at Phoenix College worked with the Phoenix College Chief Information Officer during an 80-hour paid externship program to learn about the technology and gain first-hand experience with it. The four externs were a diverse group of two women and two men in their early twenties, originating from Mexico, Nepal, Somalia, and the Democratic Republic of the Congo. All externs held part-time or full-time jobs in non-ICT fields and were taking ICT courses during the externship. They had applied for and formally interviewed for the 80-hour externship position, before onboarding as paid employees. The purpose of the externship was to gain hands-on, real-world experience working with ICT solutions to advance their career goals. Teamwork, presentations, writing, managing their schedules, and other employability skills were also part of the bundled experience. Initially the externs spent time learning about the digital divide in education by looking at case studies from different locations around the world. They also studied the technology landscape. Other activities included a site visit to local installation points and comparing device data sheets. During hands-on work with four devices, the externs created written instructions and videos showing high school students how to setup and care for a PHX DECC device in their home. The externship closed with demos of the devices and a group presentation.

4. SOCIO-TECHNICAL INTEGRATION RESEARCH (STIR)

During the externship which ran from July 26 to Oct 1, 2021, an embedded social scientist (ESS, also the first author) from Arizona State University's School for the Future of Innovation in Society conducted regular STIR dialogs with three of four externs. The STIR protocol and method was chosen because of its iterative process and flexibility to incrementally adjust the protocol to make it work for the context under study and participants' styles of interaction. Because STIR is applied within the environment where participants work as they engage in daily activities, it is minimal overhead. STIR has been applied in dozens of different STEM settings, however no known STIR case studies have engaged with students in ICT undergraduate education as they contributed to a technical solution for their surrounding community.

STIR brings social scientists into laboratory or work settings together with interdisciplinary collaborators (i.e., natural and physical scientists, and technologists who are experts) to engage in reflexive dialogs designed to probe capacities for responsible innovation (Fisher and Mahajan, 2006). STIR is unique because its methodology touches deeply on three general features shared in the broader field of collaborative sociotechnical integration that seeks to broaden the societal aspects that technical experts consider in their day-to-day activities (Fisher et al., 2015). STIR includes a collaborative decision protocol (Fisher, 2007) used by the social scientist and the participants to discover and unpack the social and technical aspects of decisions together. The collaborative discussions occur on a regular basis, on-site where the work is happening and as it is happening. The discussions have been shown to productively disrupt practices and to generate changes that are systematically documented in an ongoing process of description of the evolving knowledge production. The protocol is used to structure collaborative discussion but avoids advocating for substantive values and pre-determined agendas. Changes are captured using a framework for identifying midstream modulations (MM) of technological trajectories. As participants become more aware of the societal contexts in which they already work, midstream modulation refers to alteration of ongoing technology development activities in accordance with broader societal goals, considerations, or influences (Fisher and Mahajan, 2006).

Originally designed for research settings, STIR has also been adapted for teaching and learning in education settings. Two case studies were particularly informative of the current research study. Lukovics et al. (2019), tested an adaption of STIR with students of natural science at the University of Szeged, Hungary. The focus of the study was to facilitate responsible research and innovation awareness in Generation Z students. Instead of one-on-one STIR dialogs with experts about their daily activities, the researchers conducted weekly STIR focus group discussions with seven undergraduate students about 'what-if' scenarios based on historical examples (Lukovics et al., 2019). Each week, one student delivered a short presentation about a historical example and its associated responsible research and innovation (RRI) issues, after which the focus group engaged in a facilitated STIR dialog. An in-class group of forty-nine students heard lectures about social, economic, and ethical aspects of scientific research, but did not participate in STIR focus group discussions. Both groups of participants showed increased awareness in their sense of importance of RRI. However, the focus group participants displayed more dramatic changes in awareness and reflexivity.

In another case study, STIR fostered socially reflexive capacities in institutions contributing to the development of municipal energy systems in the Phoenix metropolitan area (Richter et al., 2016). In this scenario, STIR was used to study how energy expert decisions reflected broader imaginaries that drove development of the energy system and ongoing transformations that affected social capital within embedded and shifting value systems. Although actors in this scenario expressed more reflexive awareness towards the societal outcomes of their work than academics in lab settings, their awareness was oriented to relevant technologies and capital generation rather than system-wide issues of design, operation, and social impact.

5. STIR DATA COLLECTION AND ANALYSIS

The experimental design for the eleven-week STIR study with digital divide externs consisted of one control participant (C1) and three STIR participants (S1-S3). All four externs participated in two semi-structured interviews of 24 identical questions at the beginning and end of the study to identify differences between control and STIR participants and changes in individuals' conceptions of socio-technical integration after participating in the study. Additionally, three externs each participated in four to six individual STIR dialogs with the ESS. Other data streams included group observations and artifacts created by the externs.

5.1 Protocol for STIR dialogs

The STIR protocol uses collaborative inquiry that maps to the four quadrants shown in Figure 1. The notes and sketches from a STIR dialog are captured in a four-quadrant form, beginning in the upper left corner, and moving clockwise around the form in an iterative manner. Initial prompts are provided in each quadrant, but these are contextualized as the real-time dialog unfolds. At the end of a STIR dialog the ESS summarizes the main topic, dialog flow, and highlights any defacto, reflexive or deliberate modulations (Fisher and Mahajan, 2006). A defacto modulation occurs when participants decisions are influenced by existing human, social and material aspects that shape their technology projects. A reflexive modulation occurs when participants become more aware of the role of de facto modulation in their technology decisions. A deliberate modulation occurs when insights from reflexive modulations alter participants' decisions and practices. In between STIR dialogs, and at the beginning of each subsequent conversation, before starting a new STIR dialog, the ESS investigates new developments related to the previous discussion. The ESS seeks to iteratively analyze and reconstruct modulations from ethnographic observations, participant-observation, by examining documents and artifacts, and from developments described in STIR dialogs.

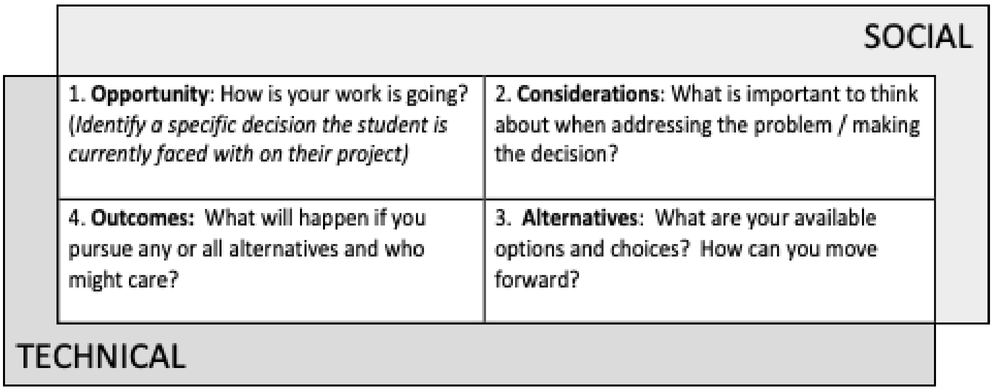

Figure 1. STIR Protocol and initial prompts. (Adapted from Fisher and Mahajan 2006, Schuurbiers and Fisher 2009).

5.2 Pre- and Post-Study Comparison of Participant Conceptions/Notions

Tables 1 and 2 capture responses from the control and STIR participants to example questions asked during the pre and post interviews about technology and societal considerations in their project. Defacto conceptions are inferred from pre-interview responses. Two types of comparisons were performed with this data: 1) a macro comparison across control and STIR participants, and 2) macro level pre/post differences that add to the micro level STIR analysis for each participant. Pre- and post-study results were largely consistent with the observed modulations.

Table 2. Participant responses to ESS inquiry about considerations for technology decisions in their project

	What kinds of considerations play a role in technology decisions [in your digital divide externship]?	
	Pre-study Response	**Post-study Response**
C1	"Making students aware that the problems faced in pandemic could occur again, so be prepared. Enabling students to help society in the future."	"We have many possible devices. Pick the one that is easiest, simplest for students to set up."
S1	"My experience"	"How this helps the community, education, during the pandemic. If they don't have access they are at disadvantage, they need it for their lives. It will a bigger problem as time goes on."
S2	"Be more cautious of what they have or don't have. Ask instead of assuming. Then just communicate with them. Provide them with what they need, explain basics step by step, how to use it."	"Find out more about how the device works, all the way to getting the [CBRS] signal to help with reasons why certain devices should go to different environments."
S3	"This is a new generation --internet, connectivity and how it brings us together and is part of our daily living. It's a good thing to see someone giving it to the community and helping high schoolers to benefit from this project."	"Where is it going to be, the people who it will benefit and how, will they be able to afford it."

In Table 1, all responses from externs at the end of the study were more specific to their considerations in the context of providing technology solutions for the digital divide in education. C1's post-study response narrowed from a broader societal statement to simplifying the technology choices for high school students. S1, who initially felt inexperienced in making technology decisions for the digital divide, and who participated in the most STIR dialogs, surprised the ESS with a post study response contextualized to the current situation, but also surfacing future issues from growing inequities. This was somewhat inconsistent with his initial strong focus on learning the technology. S2 expressed a strong desire to dig more into the inner workings of the technology to make better choices about who gets which device. Finally, S3's post study response showed consistency with the pre-study response and STIR conversations but the societal considerations in the post study response were contextualized to particular parameters that also applied to technology decisions.

Table 2. Participant responses to ESS inquiry about personal opinions for societal considerations in technology decisions

	What role does your own personal opinion on societal considerations play in determining the direction of technology decisions in your project?	
	Pre-study Response	**Post-study Response**
C1	"I'll be able to see possibilities on their behalf." [those who need connectivity]	"I make a final decision from guidance provided by the supervisors, keeping high school students in mind."
S1	I consider the people who need it most and would want to include them. I would want to know what they need internet access for: school, work, or business."	"We got a process or framework for doing this moving forward. I made the smaller decisions in my work."
S2	"It wouldn't just be the opportunity for better education. I know how it is when people are down, and they think they can't do it."	"The people's needs: they need free internet access for education and do not need to worry about costs. Also translating instructions, videos to Spanish."
S3	" It probably won't impact [technical] decisions … As long as it is not bad for them."	"We followed the rules, what [instructor] asked us to do. He gave us flexibility and options. He gave us ideas; we took what he said and made it better."

In Table 2, externs' post study responses show greater awareness of practical insights for the impact of their personal opinions on societal considerations in technology decisions. In addition to realizing the role of their personal opinions in the digital divide externship, two externs, S1 and S3, recognized a way of re-framing their thinking to apply higher level guidance to their own tasks for greater impact. S2 expanded his pre-study response by recommending Spanish translation of instructions and videos, as ideated during a STIR dialog.

5.3 Observed Modulations

Modulations were observed for all STIR participants but varied as shown in Table 3. All participants showed reflexive learning and deliberate adjustments related to technologies used in the digital divide project. Societal considerations were present in the reflexive learning for only S3, who also experienced reflexive learning that considered human dimensions and to a lesser degree, technical dimensions. In contrast, S1's learning and behavioral adjustments were mostly technical, although there was one modulation that considered human dimensions. S2 sometimes described human considerations, after first explaining technical details.

Table 3. Variation of Technical, Human, and Social Modulations across participants

	Tech	Human	Social	Example Excerpt
S1				"I watched the videos from the session, they helped but I am still digesting all the info. When I see CBRS in the documents it is starting to make sense."
Reflexive	1	1		
Deliberate	3			
S2				"Parents ... might have to help with the setup. Many do not understand English well, in my experience. ... I highly recommend it. ... If [instructor] wants me to I can go ahead and work on the Spanish one"
Reflexive	4	5		
Deliberate	1	1		
S3				"I would start with a personal understanding / story to set the stage," [before describing the detailed device setup instructions]
Reflexive	1	4	3	
Deliberate	1			

The modulations in Table 3 arose initially from STIR dialogs; some were confirmed during group observations and by examining documents and artifacts created by the externs as shown in Figure 2. For example, during STIR dialogs, externs worked through considerations, alternatives and desired outcomes that helped them think through approaches to make videos and instructions for end user devices that provided step by step setup information with pictures. In follow-up discussions, when the ESS asked externs about their progress since the prior STIR dialog, they described their accomplishments. Then, by looking at the device videos and documents, the ESS could see what was created and how it related to the STIR dialogs. The externs also participated in group sessions and demonstrations that were observed and recorded by the ESS.

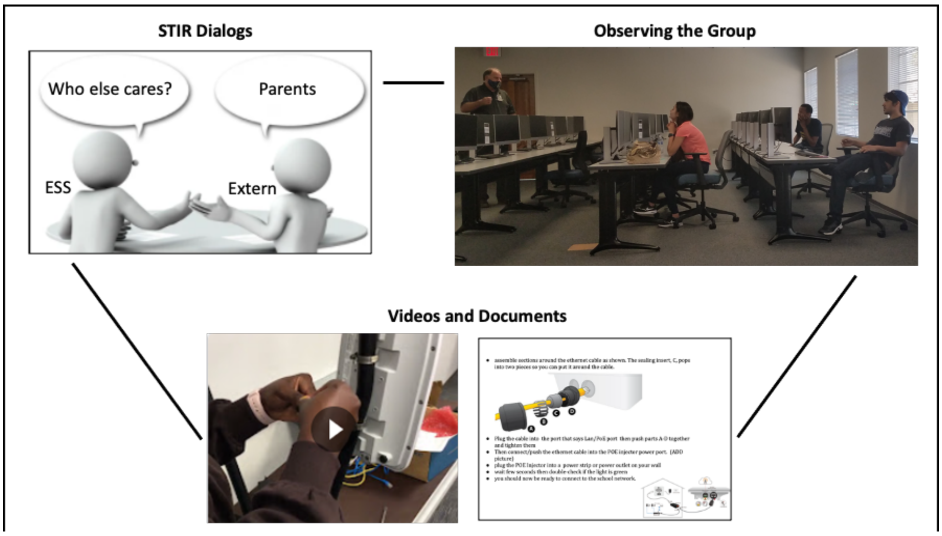

Figure 2: Triangulated Data Sources

5.4 Example STIR Narrative

Including an example STIR narrative in this paper provides context for how STIR dialogs unfold and interact with midstream modulations over time. The mini sequence in Table 4 captures key moments during STIR sessions with S3 that demonstrate deepening awareness for community context and human dimensions while also learning the technology. The items in the sequence represent modulations, namely, changes in reflexive learning about the context and content within the project followed by subsequent actions and practical adjustments. The ESS identified a defacto modulation in S3's pre-study interview, that her personal opinion would not impact technology decisions, unless the technology might cause harm, in which case her intervention might be needed (Table 2: S3 Pre-study response; Table 4: T0).

Table 4: Deeping Awareness for Community Context and Human Dimensions while also Learning the Technology

Time	Excerpt / Observation	MM	Dimension
T0	S3's personal opinions on societal considerations "probably won't impact [technical] decisions…as long as it is not bad for them."	De facto baseline	Social, Technical
T1	"Community - high schoolers ... get benefits - connection to the internet, get schoolwork done outside of school, and motivation." [Shows expansion of S3's conception of the community context beyond T0 to include positive benefits from her technical decisions.]	Reflexive Learning - Context	Social, Human
T2	"Where High School students live, where their school is" [Shows expansion beyond T1 to include socioeconomic factors in S3's technical decision making].	Reflexive Learning - Context	Human, Social
T3	"I would start with a personal understanding / story to set the stage," [Shows broadening of a technical task to include reflexivity and human dimensions].	Reflexive Learning - Reflexive	Human
T4	"Community, school district, parents, and students care because it helps them with schoolwork and life." [This is an expansion beyond T0 and T1 that includes future prospects in addition to near-term benefits.]	Reflexive Learning - Context	Social, Human

Later, during a STIR dialog, the ESS and S3 discussed how S3 should finish digging into the technology landscape for the digital divide. Important considerations included: Understanding the technology, the Digital Divide goals and "Making sure I do it right." The dialog partners talked about alternatives for how to do the task: Using computers, Searching the web, Reviewing and sharing PowerPoints, and Reading emails w/ instructions and links. The outcomes that they discussed for all the alternatives were: Success in getting work done (extern and the group), Learning (extern and the group) and (the group leader) applies our ideas in the Digital Divide solution for high schoolers.

ESS: Who else might care about your successful outcomes with the Digital Divide?
S3: The Government is proud of the accomplishment because their investment pays off... [also the] Community - high schoolers care because they get benefits: connection to the internet, get schoolwork done outside of school, and motivation.

The ESS identified the latter remark as a Reflexive modulation (Table 4: T1), because S3 realized something she had not articulated before, namely, that her learning the technology and "getting it right" by pursuing alternatives 3) and 4) could impact the community and high school students in positive ways, an expansion on the de-facto remark during the pre-interview that her personal opinion would not impact technology decisions, unless the technology might cause harm, in which case her intervention might be needed. In the reflexive modulation, S3 broadens her notion of moral agency for a technology development to include not only preventing harm but also improving the technology to better serve members of the community.

A subsequent STIR conversation focused on a technical deliverable, creating instructions to explain how to set up and care for an ICT device at home. Initial considerations were technical, e.g., SIM card, device.

ESS: Are there any other considerations?
S3: Where they live, where their school is.

The latter comment considers socioeconomic factors, as many of the families in surrounding neighborhoods are below poverty level incomes. Some live in apartments, and many are renters. The ESS identified this as Reflexive Learning (Table 4: T2) in the context of the families receiving the technology devices, and how it impacts which device they are assigned, where they put it in their house, and how they orient it to pick up the WIFI signal. When the dialog partners discussed alternatives, the usual ways of using pictures, words, and a video were offered. Then a novel and interesting alternative popped up!

ESS: Are there any other ways you can think of to do this?
S3: Figure out the steps by working with the pieces and parts of the device hands on, then develop the instructions.
ESS: Anything else?
S3: I'd like to start out the instructions with a personal understanding to set the stage.

Adding "personal understanding" suggests that S3's conception of the instructions has broadened to include not only technical but also human dimensions. This is a form of learning that demonstrated Reflexivity (Table 4: T3) because S3 wanted to put a bit of herself and her story into the video deliverable to make it more relatable to high schoolers. In discussing outcomes, two possibilities arose, high schoolers can set up the device or not.

ESS: Who cares about whether the high schoolers can set up the device?
S3: The community, the school districts.
ESS: Who else cares?
S3: The parents care.
ESS: Why might the parents care?
S3: It helps their kids with completing schoolwork and in fulfilling their life.

S3's explanation of why parents might care represents Reflexive Learning (Table 4: T4), for it shows deepened sensitivity to the digital divide context and longer-term benefits to humans and society. It is part of a continuing pattern of deepening sensitivity to human and social considerations and her own role in technology decisions that has emerged from the collaborative STIR dialogs between S3 and the ESS.

6. DISCUSSION

All externs experienced learning and behavioral adjustments from their participation in STIR dialogs. Several forms of experiential learning w**ere** observed. Throughout the study, the dialogs promoted two-way learning between the externs and the ESS. Together they learned about the technical and social (including the local community) contexts and constraints of the project. The ESS also learned how to apply STIR in the context of the study as well as the perspectives and experiences of the externs, and how these changed over time.

In terms of socio-technical learning, the externs built initial capacity to sense and respond to human and social dimensions of technology as they learned new ICT skills. Furthermore, the observed socio-technical learning led to deliberate adjustments related to technologies used in the digital divide project.

The STIR protocol also aided in documenting and showing how the observed socio-technical experiential learning deepened over time. S3, unlike other externs, considered the larger societal goals and future outcomes in the face of learning a new complex technology in a short period and being assigned very technology-oriented tasks. The STIR dialogs deepened her existing sensitivity to societal dimensions from her background and experiences as a Native African immigrant who escaped poverty.

Although the digital divide group leader frequently raised socioeconomic considerations while talking about technology, and provided case studies from other digital divide projects, as tasks became more technical in the progression of the externship experience, S1 and S2 made less reference to the community and societal considerations, even though they each demonstrated technical learning. S3 continued to keep the community and the high school students in mind while she worked on the technology pieces. These results suggest that using STIR meets learners where they are currently at in their de facto thinking and aids them in progressing to a new level of socio-technical learning and decision making.

7. CONCLUSION

Using socio-technical integration research alongside experiential learning by undergraduate ICT students led to enhanced critical-learning over time in the context of their digital divide project, enhancing the state of the art for undergraduates' experiential learning in technical fields. A new term, socio-technical learning, was coined to characterize the empirically observed steps: learning technical skills, learning to reason about societal contexts of technology decisions, and applying both social and technical learning in actual decision-making contexts. Each learner started from a different beginning point and each took a progressive "step" forward. More deliberate modulations took place with technology than with human or social dimensions. That said, reflexive modulations added to enhanced critical learning and deepening community sensitivity over time, especially for S3. Challenges encountered in the study included, adapting the STIR vocabulary to English as a second language (ESL) learners and fitting the STIR dialogs into busy schedules. A weekly cadence was not always possible, as all externs were enrolled in classes, working full-time or part-time jobs, and balancing family activities with academic and work activities. The target sample size for the study was initially six of ten externs: four STIR and two control participants. Instead, the study was limited to four externs who were hired for the Digital Divide project: three STIR participants and one control participant. Plans are underway to explore additional STEM undergraduate work-based experiences with diverse externs at similar institutions and will recommend deploying socio-technical learning in an iterative manner that progresses one step at a time. A potential extension to this study might explore how work supervisor and/or faculty openness to considering human and social dimensions in technology decisions impacts the critical learning and deepening community sensitivity of the group.

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