Altering Current Plate Reader Technology for Use in Classrooms

Impact of Technological Implementation in Education

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Bachelor of Science in Biomedical Engineering

By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The ability to measure and quantify biological data is crucial for progressing experimentation and discovery within the scientific community. Without data any results from experiments would either be nonexistent or disregarded by the community. In order to gather and record the data that makes their results viable scientists have used a wide variety of scientific equipment and tools. As technology has advanced with an ever quickening pace, there has been much improvement to the devices and equipment used by researchers and scientists. One specific piece of lab equipment that is widely used in the study of various biological concepts is the multi-well plate reader. The device has different forms that are currently used for a variety of information gathering, as described by Jones, Michael, and Sittampalam in their 2016 review article, including “biological, chemical or physical events found within the well of a microplate” (p. 4). One of the recent advances made in the field of multi-well plate readers is their miniaturization, which allows for a reduction in their cost and an improved adaptability for different lab settings.

Recent advancements made in certain areas of technology have resulted in strong investments being made to increase the implementation of educational technology into classrooms and curriculums. However, the implementation process has come with its own set of barriers and drawbacks that often prevent the technology from being effectively implemented. The pathway that technology takes to get from engineer to student requires that it be passed through a series of other involved groups before it reaches the intended users. At each point along the pathway there are potential barriers that can stop the progress of the technology, which is why the overall network surrounding the implementation process needs to be researched and analyzed. Through research of the network potential reasons for the various barriers can be discovered and addressed in order to make the implementation process more effective.

The aim of the technical project is to adapt a current multi-well plate reader and make it more cost-effective with a better design aimed at making it an educational tool for high school aged students. The specific plate reader that will be modified is the Stratus L.E.D.-based plate reader created by Cerillo, a Charlottesville based startup company. The Stratus is a miniaturized plate reader that has proven useful in a laboratory setting, but is still too advanced and expensive to be a realistic educational option. Along with the newly designed plate reader a curriculum that includes basic protocols for experiments which teach various biological concepts will be developed. Because the aim of the technical project is to make a piece of technology more accessible and useful for educational settings and develop a curriculum that incorporates this technology it is tightly coupled to the Science, Technology, and Society (STS) research project, which will focus on identifying the barriers that prevent educational technology from being effectively implemented into a classroom. Using a linear actor-network model, the research project will examine how the technology is passed from actor to actor before reaching the intended users, which are the students. By tracking the progress of the technology, the possible barriers that hinder implementation will be analyzed and the common social themes that emerge will be used to construct the network surrounding the linear handoff model.

Project personnel for the technical project will include Michael Ramirez, a fourth year biomedical engineer at the University of Virginia, who will be a co-leader of the project. There will also be two mentors for the project who are both employees of Cerillo, the startup company whose resources and product will be used for the duration of the project. Those employees are Kevin Seitter, Chief Technology Officer (CTO) and co-founder, and Kristin Schmidt, product development engineer. Professor Timothy Allen, of the biomedical engineering department at the University of Virginia, will act in an advisory role. The timeline for the technical project will follow the deadlines of a year-long capstone course in the University of Virginia biomedical engineering department. The timeline for the STS research project will follow the deadlines set by a year long thesis based course. Milestone goals for individual components of each project can be seen in Figure 1, shown below.

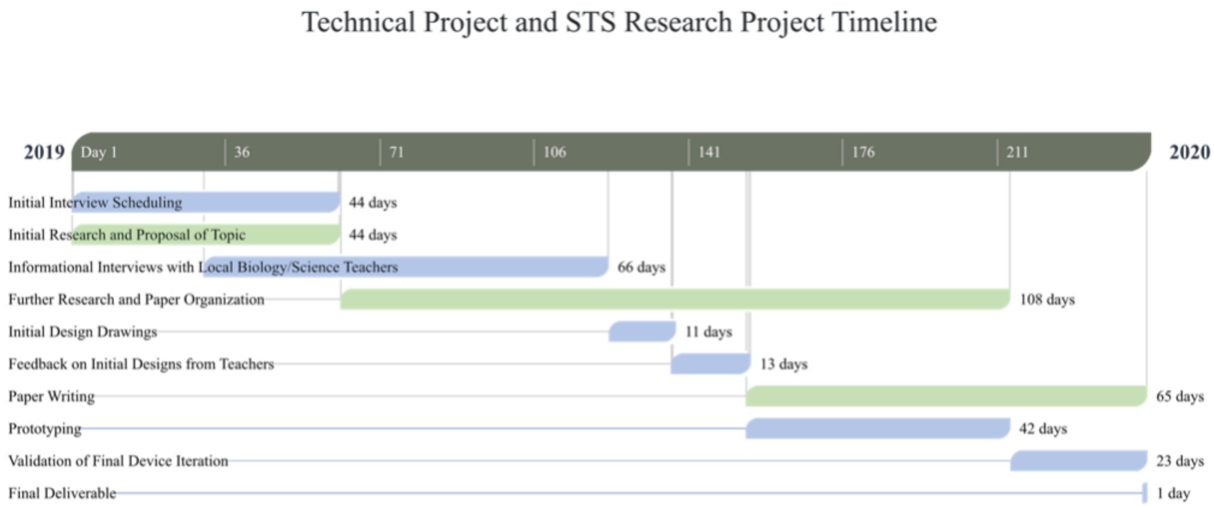

Figure 1: Gantt Chart: Timeline for the planned milestones and goals for both the technical and STS projects. The milestones for the technical project are shown in blue and those for the STS project are shown in green (Billips 2019)

EDUCATIONAL PLATE READER

According to the webpage of BMG Labtech (https://www.bmglabtech.com/microplate-reader/), a plate reader development and sales company, the multi-well plate reader is capable of detecting light emitted from samples in the wells and turning the photons into electricity that can then be interpreted by a computer. The emitted light is a result of a chemical, physical, or biological reaction occurring in the sample and that reaction is the measurement being recored by the plate reader. Currently, the most common types of multi-well plate readers are large, expensive, and often complicated, which are all barriers to it being widely accessible for use in an educational environment. The plate reader created by Cerillo, which is being used as the baseline device for the design process of the technical project, has solved one of these issues by being smaller than almost any other plate reader currently on the market while still maintaining a similar level of efficiency. However, their plate reader is still not cheap enough or adaptable enough for use in a high school classroom. Schools have limited budgets and the purchase of equipment has to be justified by improved student performance. Therefore, the two main areas of improvement that the design process of this technical project will address are the cost of the plate reader and the ability of the plate reader to improve learning. Along with adapting the plate reader device, a short curriculum will be developed to accompany the device in order to make it easier to implement into both public and private schools. This curriculum will be based on topics that are currently taught in public high school curriculums and it will follow the Virginia Standards of Learning (SOLs). The aim of the curriculum is to allow the plate reader to be beneficial and impactful for a classroom that does not conduct any experiments that require a plate reader.

In order to properly design a device that will be easily integrated into existing school systems, the current curriculums used by high school teachers will have to be understood. Since the project is based in Charlottesville, Virginia the curriculums used by local area high schools will be used to determine how to design the plate reader around the lessons that teachers currently employ in their classrooms. This will involve talking to biology teachers and educational instructors within the Albemarle County school system to learn about the topics their curriculums cover, as well as, their general classroom experience. The amount and type of interactive experiments performed in a classroom will determine certain aspects of the plate reader design, including quality and range of capabilities. If the plate reader is not going to be used often, or only for teaching specific concepts, then the device does not need to have functions that will never be used. On the contrary if the device would be useful for teaching multiple concepts and the teachers express interest in incorporating the plate reader into multiple parts of their curriculum then the design will involve more functions. Discussions with the teachers about their curriculums will also provide a baseline for the development of the accompanying curriculum.

Once the curriculums are understood and how the eventual plate reader will be implemented into them is decided the design process will begin. Since the technical project's aim is to adapt the current plate reader being sold by Cerillo some aspects of their mechanical design will likely remain unchanged. The original design for the Stratus plate reader was created by four members of the biomedical engineering department at the University of Virginia, Paul Jensen, Bonnie Dougherty, Thomas Moutinho, Jr, and Jason Papin (2015). Those four created a low-cost miniaturized plate reader meant for optical density measurements in 96-well plates which was described in their design and validation paper, shown in Figure 2. Their design included two plates of light-emitting diodes that are placed on the top and bottom of an aluminum frame that transmit light through the sample and are absorbed and translated by phototransistors (p. 52). The structural design of the plate reader will likely still be used for the new educational model since it is what allows the device to be smaller than other plate readers. However, other aspects of the Stratus plate reader can be easily changed to accommodate the budget and function needs of the schools. Some of the possible adaptations include reducing the

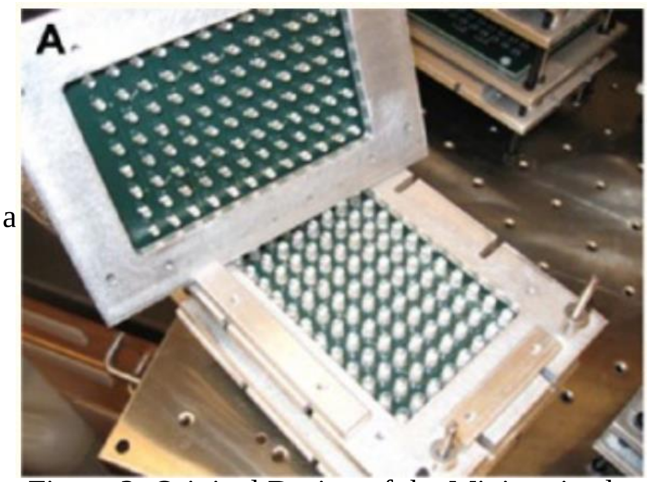

Figure 2: Original Design of the Miniaturized Multi-Well Plate Reader: The mechanical and physical structure of the plate reader from which the current Stratus model is based (Jensen et. al., 2015)

number of wells that the device is capable of reading and using lower cost materials. Both of these changes would benefit a classroom setting since most classroom sizes would not require 96 wells for experiments and they would not need the materials to be as high of a quality that most biology labs desire.

Inspiration from other innovative plate readers will be considered when designing the educational plate reader. For example, a hand-held microplate reader was created by several professors at the University of California, Los Angeles, and it was designed to address issues with using enzyme-linked immunosorbent assays (ELISA) in the field and in resource-limited settings due to the size and expense of the currently used machines that are necessary for getting the data readouts. In their design paper (2015) the professors described how the data from the multi-well plate would be recorded with the final step being that "a matrix of these quantified clinical index values (one for each well) is transmitted back to the cell phone" where the user could then view the data through a smartphone app also designed by the professors (p. 7861). An innovation like that will be considered for the educational plate reader since access to the information might be crucial in some classrooms, and most students have smartphones in their pocket.

The final step for the technical project will be to validate the final device that is created. This will involve performing multiple basic biological experiments that are easily reproducible and comparing that data to data collected from some of the common multi-well plate readers. If the results of the educational plate reader are within 5% of the results from the more expensive plate readers then the device will be considered operational and capable of being used for experiments in the classroom. The validation process is important for confirming that the device created can be used in a multitude of experiments and conditions since it will be used in multiple classrooms that all have different curriculums and standards. Michael Chavez, Johnathan Ho, and Cheemeng Tan, who are all members of the department of biomedical engineering and college of biological sciences at the University of California Davis, were concerned about the lack of reporting critical experimental settings for plate reader assays, and in their 2017 study they found that 76% of scientific papers that used a plate reader did not specify how the plates were prepared (p. 375), which indicates the importance of plate reader results being reproducible under different circumstances. Reproducibility within the biomedical community has been a growing concern and Francis Collins and Lawrence Tabak (2014), who are the director and principal deputy director, respectively, of the US National Institutes of Health (NIH), discussed these concerns in their article, which also explained the NIH plan to combat this issue by creating training modules that put emphasis on reporting procedures and good experimental design, and creating a database where scientists can see any unreported primary data (p. 612). These NIH procedures and resources will be considered during the plate reader design process since it will potentially be used in classrooms across the country and learning proper documentation methods for reproducibility is important to couple with an educational device.

WHAT STOPS TECHNOLOGY IMPLEMENTATION IN EDUCATION?

Technology is advancing and evolving at an ever quickening pace, and there has recently been a strong push to implement more technology into school systems and classrooms. Integration of technology into curriculums can be especially useful for engineering fields since advanced technology has greatly increased the research capabilities of those fields. However, despite a shift towards technology implementation, there are many barriers that can often prevent the technology from ever being effectively used by the intended users, which are the students. In order to understand why educational technology is sometimes prevented from being effectively implemented, the pathway, that gets the technology from the engineers who design it to the students who use it, must be examined. This pathway will be illustrated using a linear actor-network model developed by W. Bernard Carlson, a professor at the University of Virginia. The model is based on Actor Network Theory (ANT), which looks at the network surrounding various social groups and shows how a complex web of relationships and factors influence each

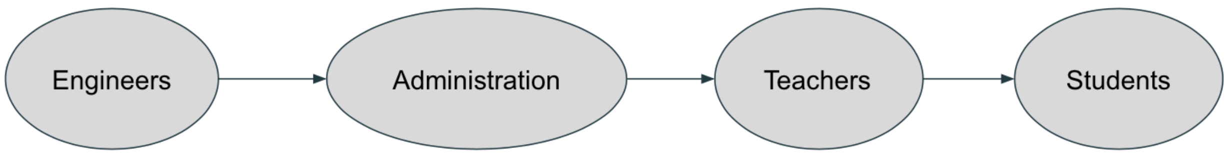

Figure 3: Initial Educational Technology Linear Actor Network Model: The flow of technology from engineer to the eventual end user, which are the students, must first pass through the teachers and the administration (Billips, 2019)

of the groups.

Shown below in Figure 3, the linear actor-network model represents the pathway that educational technology follows for classroom implementation. The process starts with the engineer passing the technology to the administrators who are responsible for determining if a particular technology is worth funding and integrating into a school. If the administrators approve of the technology it is then distributed to the teachers who are responsible for finding effective means of using the technology in their classrooms and curriculums. Finally, the technology is passed from the teachers to the students through those teaching methods in the classroom. This model is an ideal scenario, where the technology passes from group to group without hinderance and the students are able to use the technology to its fullest, just as the engineers intended. Unfortunately, this is not realistic as there are many barriers that occur at each stage of the model and between each pair of groups. The following sections will identify these possible barriers and analyze how that affects the effectiveness of the technology for improving learning.

BARRIERS BETWEEN THE ENGINEERS AND THE ADMINISTRATION

This portion from the linear actor-network model is one that is directly experienced as a result of the technical project. The aim of the technical project is to take a piece of technology designed by engineers and implement it into schools, which will inevitably mean talking to administrators about various aspects of the technology. The concerns of the administration must be addressed by the engineers if the technology is to overcome those initial barriers. A specific goal of the technical project is to make the technology cost effective for a high school budget. According to an article written by Doug Johnson (2012), the director of media and technology at Mankato Area Public Schools in Minnesota, K-12 schools across the United States spend, on average, about $400 per student per year for educational technology. However, Johnson also warns that district budgets are shrinking and technology departments will have to be more frugal when it comes to what technology they choose to invest in and implement. Less money in the budget means that administrations will be less likely to take the technology from the engineers and continue on the implementation pathway.

Since administrators are concerned about budgetary issues they will be examining any proposed technologies very carefully and will attempt to gauge the actual usefulness and safety of the technology. This means examining and measuring the effects of the technology on students’ learning to determine if it is worth using part of their budget. It also means that engineers need to study the impact of their technologies on student performance if they are to overcome this barrier. A study done in 2016 by Jesús Moreno-León, Gregorio Robles, and Marcos Román-González, who are all professors of computer engineering at various universities in Madrid, Spain, did just this by looking at the impacts of learning a coding language at various stages of education and when the appropriate time would be to introduce programming languages into a curriculum. They found that when the same programming language was introduced to both 2nd and 6th grade classes it “significantly accelerated the learning curve” for the 6th graders, but did not for the 2nd grade group (p. 296). These results show that while technology can be beneficial to education, the same technology can have other impacts, or no impact at all, depending on certain factors. Therefore, engineers must keep this in mind when designing their technology if they want to overcome that barrier and stay on the pathway for implementation.

BARRIERS BETWEEN THE ADMINISTRATION AND THE TEACHERS

If the technology is successfully passed from the engineers to the administration, the next step would be the distribution of the technology to the teachers. Unfortunately, this also comes with a series of obstacles that prevent effective distribution and integration. One obstacle is the accessibility of the technology for the teachers. Ideally the technologies would be available for every teacher all the time, but realistically it would be too costly for the administration to achieve. Lin Carver (2016), an associate professor of graduate studies in education at Saint Leo University in Florida, investigated what teachers thought some of the barriers to implementation might be through an anonymous survey, and she found that teachers believed accessibility to equipment was the biggest barrier (p. 114). If teachers believe accessibility will be limited they will be less willing to effectively integrate the technology into their classrooms.

Even if the technology reaches an acceptable level of accessibility, there is an issue of how the technology will fit into the already existing curriculums, or if the curriculum would have to be restructured to accommodate the new technology. Identifying areas of learning that are important for inclusion in the curriculums can help the administration seek out the technologies best suited for assisting with those subjects. For example, in a paper written by Jennifer Buelin (2016), who works for the Center for Teaching and Learning in Reston, Virginia, Aaron Clark, a professor of graduate programs at North Carolina State University, and Jeremey Ernst, an associate professor and associate director for the Office of Educational Research and Outreach at Virginia Tech, explored which of the 14 Grand Challenges for Engineering in the 21st century, as stated by the National Academy of Engineering, would be appropriate to incorporate into the curriculums for elementary to high school aged students. The study involved giving a panel of experts various surveys regarding how relevant and how appropriate the challenges would be for elementary, middle, and high school level students. The results showed that the experts considered nanotechnology to be the most appropriate challenge for curriculums to focus on for high school students (p. 47). Overcoming the barrier of curriculum flexibility is important for the effective distribution of technology from the administration to the teachers.

Once the curriculum is completed and the appropriate technology for it is selected, there could still be problems with how willing the teachers are in terms of using the technology in their classrooms. A study done by Feng Liu (2017) from the American Institutes for Research, Albert Ritzhaupt and Kara Dawson from the University of Florida, and Ann Barron from the University of South Florida, also found that that certain factors, such as number of years teaching, access to technology, and gender had either positive or negative impacts on how confident and comfortable the teacher was at using the technology in the classroom (p. 810). Generally, teachers with more years of teaching and less access to technology might be more resistant to implementation since they might not know how to use the technology to its fullest potential. If the administration is to overcome this barrier it must find ways to train the teachers with the technology so that the teachers can feel more comfortable using it in their classrooms. Once the teachers feel comfortable enough with the technology it can continue on the implementation pathway and be passed on to the students.

BARRIERS BETWEEN THE TEACHERS AND THE STUDENTS

Some of the barriers that arise between the teachers and the students are a result of the barriers from previous parings not being fully addressed. For example, a teacher's willingness to implement the technology into their classroom is affected by the retraining efforts of the administration. If the teachers are not willing to use the technology then they might use it in an ineffective manner, which dampens the impact it has on the students' educational success. Another barrier between the teachers and the students that stems from previous barriers is making sure the selected technology is appropriate for the age group in the teacher's classroom. As discovered by Moreno-León, Robles, and Román-González, certain technologies are better suited for students of a certain age range. If this issue is not overcome when the administration is selecting technology from the engineers then it can lead to teachers using inappropriate technology for their students.

However, even if the selected technology is age appropriate and the teachers have been trained in its effective use, there could still be problems with how the teachers decide to implement the technology into their lessons. In a study conducted by Marta Domingo and Antoni Garganté (2016), who are both in the department of psychology and educational science at the Open University of Catalonia, the two professors looked to understand teachers' perceptions of using mobile technology in the classroom and how they think it impacts learning. The survey results found that, despite most teachers viewing mobile technology's biggest impact was facilitating information in the classroom, some of the applications used most often by the

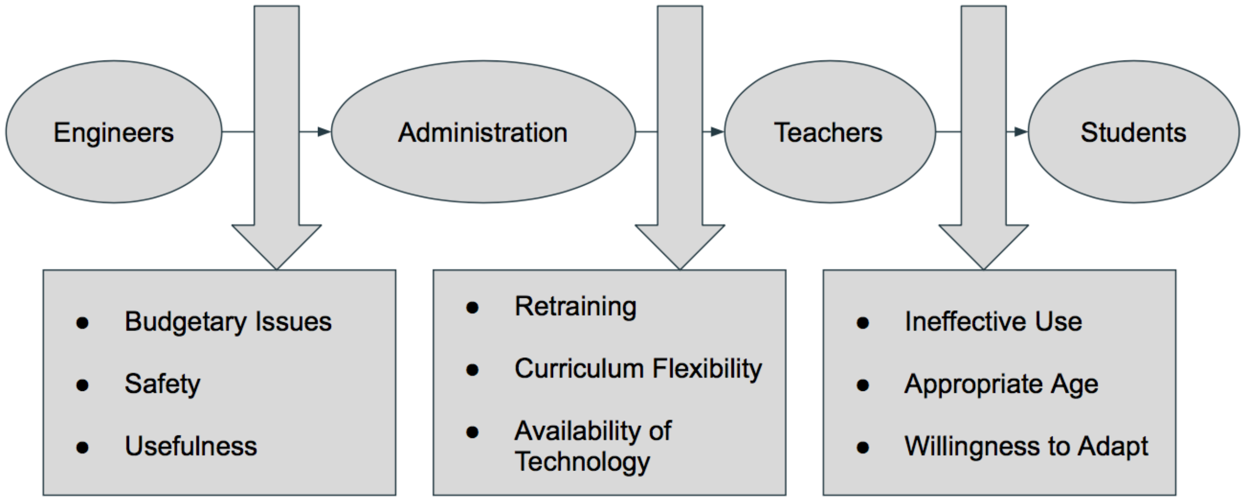

Figure 4: Revised Educational Technology Linear Actor Network Model: Contains original flow of technology, but this version now includes the barriers that occur in between each step of the pathway (Billips, 2019)

teachers did not have a strong impact on learning. The study exemplifies how ineffective use of technology by teachers can be a barrier for effective implementation.

THE BIGGER PICTURE

The linear actor-network model for effective educational technology implementation, shown in Figure 3, was created with idealism and optimism instead of realism. It would be great if technology could be implemented into a classroom as easily as the model displays. Unfortunately, the barriers discussed above are not just possibilities, but rather inevitabilities. That is why a more accurate model for the educational technology implementation pathway is shown below in Figure 4. This model is still based on the linear actor-network model, but it includes the barriers that occur between each step of the pathway. Initial barriers between the engineers and the administration include budgetary issues and concerns over the technology's safety and usefulness. The barriers that prevent the technology from being distributed from the administration to the teachers include difficulty in retraining teachers, creating curriculum flexibility, and ensuring the technology is accessible for the teachers. If the technology is able to overcome the first two sets of barriers there are still barriers between the teachers and the

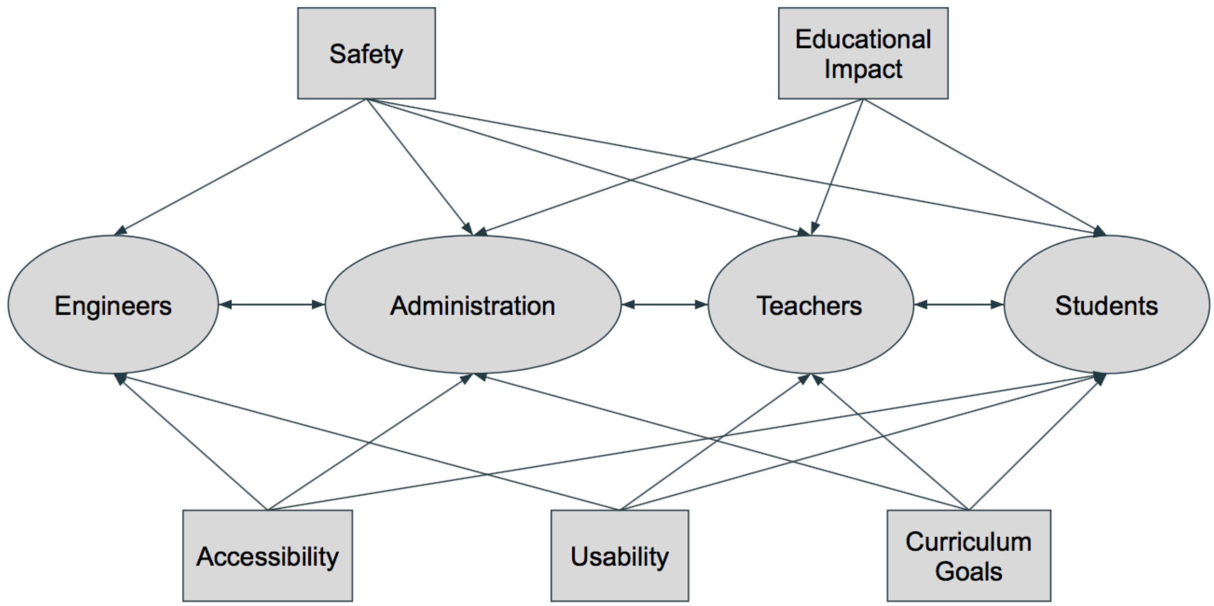

Figure 5: Full Network of the Educational Technology Implementation Process: Shows the various social factors that influence the actor groups previously discussed in the other models. The result is a couple network of influences (Billips 2019)

students, including ineffective use of the technology by the teachers, issues with finding age appropriate technology, and a willingness by the teachers to adapt to the new technology.

With this new model for educational technology implementation being a more realistic overview of the process there are common causes and themes that can be extrapolated from the various barriers. When placed around the original four social groups, these commonalities start to form a complex network of relationships and social influences that surround the four actors. Shown in Figure 5 on the next page, the proposed network includes social forces such as; safety, accessibility, educational impact, usability, and curriculum goals. Each of the forces affect multiple actors and the actors themselves are also shown to affect each other instead of only the initial actor influencing the next actor in sequence, which is seen in the two pervious models. The aim of the research project will be to investigate these social forces and understand how they affect the overall implementation of educational technology by influencing each individual actor group. It is also entirely possible that even more social factors will be discovered as the ones shown in Figure 5 are more thoroughly researched. However, the main goal will be to understand the network surrounding educational technology implementation and how that network creates barriers that prevent effective integration. Research will be accomplished primarily through literature review, but since the technical project is focused on educational technology implementation there is an opportunity for first-hand experience with the process, as well as, the possibility of interviewing members of each actor group to understand individual perspectives on the process.

In 2001 Sarah Butzin, an author and scholar who has focused on how learning environments are created for improved educational experiences, conducted a study that aimed to examine the effects of technology in learning environments by looking at similar technology filled schools, but one school implemented a program called Computers Helping Instruction and Learning Development, or Project CHILD. The project involved implementing a computer station that had at least three computers into a classroom, and then comparing standardized test scores from that classroom with a classroom that did not have these stations. After three years of having the computer station, the students who participated in Project CHILD were found to have higher test scores than the students who did not have the computers. This study shows how proper implementation of technology can have positive impacts on students' educational success, and why it is important to analyze the implementation process so that all educational technology can be this impactful.

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