PROBLEMS WITH THE EDUCATIONAL TECHNOLOGY IMPLEMENTATION PROCESS

A Research Paper submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By

Peyton Billips

March 27, 2020

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.

ADVISOR
Catherine D. Baritaud, Department of Engineering and Society

CREATION OF EDUCATIONAL TECHNOLOGY AND ITS IMPLEMENTATION

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. A multi-well plate reader 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. A Charlottesville based startup company, Cerillo, is one of the leading innovators when it comes to the miniaturization of plate readers, and their current product, the Stratus, is currently the smallest plate reader on the market. The technical project aimed to adapt Cerillo's current plate reader technology for use in an educational environment by reducing the manufacturing cost and redesigning the plate reader to meet the specific needs of a classroom. Along with the newly designed plate reader, a curriculum was developed that includes basic protocols for experiments, teaching various biological concepts.

Creating and implementing a piece of educational technology into the learning experience can greatly enhance the success of the students using the technology. Sarah Butzin, an author and scholar who has focused on the improvement of educational experiences through

the structure of the learning environment, was able to show technology's benefits on education through her 2001 study that focused on the implementation of computers into elementary school classrooms. By placing computers into the classroom, and modifying the curriculums to effectively incorporate them, students were shown to have better test scores for all subjects when compared to their peers who did not have access to the technology (p. 371). Butzin's study exemplifies the positive effects that effective implementation can have on the learning environment and a student's success. However, not all technology has been shown to increase student performance, or create a better classroom. When this occurs, it is often the technology itself that is blamed, with critics arguing that the technology has failed, or was poorly designed for education. While poor design can sometimes be to blame for the underperformance of educational technology, other factors must be examined as well. The Science, Technology, and Society (STS) research project aims to identify some of the other issues that contribute to the failure of educational technology to enhance the learning experience. Specifically, the STS project examines the implementation process of educational technology using the linear handoff model that was based on Biker and Pinch's Social Construction of Technology (1987), identifies barriers that prevent the technology from being effectively used in the classroom, and provides possible solutions to overcoming some of those barriers by using the Social Construction of Technology model. Since the aim of the technical project was to make a piece of technology more accessible and useful for educational settings and develop a curriculum that incorporates this technology, the technical project is tightly coupled to the STS research project.

EXAMINING THE EDUCATIONAL TECHNOLOGY IMPLEMENTATION PROCESS

The process of implementing a new technology can take many forms depending on the type of technology and the situation into which it is being introduced. A single piece of

technology's implementation process can even differ based on the environments that it is placed in and the groups that use it. These pathways often involve more stakeholders than just the engineer and the intended end users of the developed product, which leads to ineffective use of the technology. The implementation process for educational technology is no different. The first step is identifying the major stakeholders in the process and can be illustrated using a linear handoff model, based on Biker and Pinch's Social Construction of Technology (1987) and adapted by W. Bernard Carlson, a professor at the University of Virginia. Shown below in Figure 1, this model shows the important stakeholders in the implementation process, as well as the

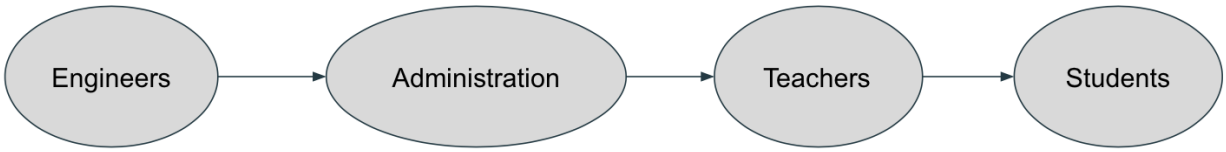

Figure 1: Initial Educational Technology Linear Handoff Model: The flow of technology from engineer to the eventual end user, which are the students, must first pass through the teachers and the administration (Billips, 2019).

order that the technology travels before reaching the end user. For educational technology, there are four main stakeholders through which the technology must pass; engineers, administration, teachers, and students. Once the technology is fully developed by the engineers, they must convince the administration of the value in implementing the technology into their schools. If the administration believes that it has the potential to improve the educational experience, they will then have to train the teachers on how to use the technology. The teachers then have to effectively implement it into their curriculums and classrooms so that the original intended end users, the students, can use the technology to its fullest potential. At each stage of the handoff model, there is an opportunity for the new group to influence the technology's implementation. However, different social factors that affect each group can lead to changes in the implementation of the technology, which can affect its overall success. Barriers can arise

between each group during the handoff process leading to ineffective implementation. Identifying these barriers is a crucial first step in improving the overall implementation process and ensuring that educational technology has a positive effect on students.

IDENTIFYING THE BARRIERS BETWEEN THE STAKEHOLDERS

The linear handoff process of implementing technology into classrooms, as shown above in Figure 1, involves many groups that all have their own goals and ideas for the technology. Social factors affecting each of the different groups can lead to barriers arising between them and thus ineffective implementation of the educational technology. The first handoff that occurs is between the engineers and the administration who decides if the educational technology is worth implementing into their school systems. The issues that the administration is concerned with often differ from those of the engineer. While the engineer is mainly focused on the technical aspects of their product, the administration considers the budgetary effects, the safety, and the usefulness of the technology. If the administration believes the technology is not cost effective, then the implementation process can stall despite the improvements the technology could offer in the classroom. Doug Johnson (2012), the director of media and technology at Mankato Area Public Schools in Minnesota, 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 (p. 30). If school systems have even less money to spend on educational technology, then this barrier could grow even larger in the coming years. Another concern of the administration is the safety of the technology.

This encompasses not only the physical safety of the students, but also their mental health. As technology has become more widely integrated into our lives, more researchers have studied its effect on mental health. The mental health of students, in particular, has also been

more closely examined in the past decade with the rising of mental health issues among students. A 2019 article written by Emily Lattie, a professor at Northwestern University in Chicago, Illinois, Sarah Ketchen Lipson, a professor at Boston University, and Daniel Eisenberg, a professor of Health Management and Policy at the University of Michigan, focused on the growing trend of mental health issues amongst college students and technology's role as both a cause and a solution. They found that an epidemiological study reported that "mental health diagnoses have risen from 22% to 36% among college student respondents over the last 10 years" (p. 1). In addition, they also found that certain aspects of technology contributed to the increase of mental health issues, especially with the increasing use of technology in colleges. These challenges concern school administrations when determining if a new educational technology should be implemented. Even though a technology might be useful for the classroom, any unwanted effects could prevent it from being incorporated into the school, or becoming ineffectively implemented.

The second stage of the handoff model for educational technology implementation involves the administration preparing the teachers for the use of the technology in the classroom. Ideally, the teachers could easily adapt to the new technology and the transition of such into their classrooms would be flawless. However, just like the barriers that arise between engineers and the administration, there are other social factors that influence the implementation process for teachers. One of the influential social factors that affect teachers is their curriculum flexibility, and the adaptability to new technology. Often the curriculums for public school systems are based on standardized criteria that has been approved by the state or country. For example, Virginia public schools must adhere to the Standards of Learning as created by the Virginia Department of Education. The topics and subjects that the Department mandates be taught

heavily influence how the teachers' curricula are structured. Teachers do have some flexibility in how they teach those subjects, but if a technology does not adequately couple with the established curriculum, then teachers may be less inclined to effectively implement the technology. Along with curriculum flexibility, a teacher's ability to adapt to the technology can also influence the success of its implementation. 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 form the University of South Florida, found that the number of years teaching, access to technology, and gender had impacts on the confidence and comfort of the teacher using the technology in the classroom (p. 810). This group also found that typically it was older teachers who were more uncomfortable with using new technology in their classrooms. The social factors found by the researchers are just some of the reasons why a teacher's willingness to use the new technology can vary, which eventually impacts the evolution of the technology. However, even if a teacher is willing to implement the technology, there is still an issue with supply. For instance, Lin Carver (2016), an associate professor of graduate studies in Education at Saint Leo University in Florida, found that teachers believed accessibility to equipment was the biggest barrier (p. 114). An unavailable technology will have no chance of impacting the learning environment. In addition, a teacher is far less likely to change their curriculum without firm knowledge that the technology will be readily available.

There are also consequences for the students when the teacher implements the technology and it is not available for the students. An award winning, education focused journalist, Alia Wong (2018), wrote about the challenges that students face when they do not have adequate access to the technology required by their teachers. One of the professors that Wong interviewed, S. Craig Watkins, describes the lack of technology access as a 'digital divide' that has become

‘an “institutional blind spot” for many school leaders and policy makers’ (para. 8). When the administration decides to implement a piece of educational technology but does not provide adequate access, there are negative consequences for the teachers, the students, and implementation process as a whole.

The final stage in the educational technology linear handoff model occurs between the teachers and the students, for whom the technology was originally intended. At this stage of the process, negative effects are often attributed to the technology itself. However, even if the teachers are willing to adapt to the new technology and implement it into their curricula, barriers can still arise between them and the students due to the misuse of the technology in the classroom and unwillingness of the students to adapt. The misuse of the technology can come in different forms. For example, 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, looked at the impacts of learning a coding language at various stages of education and determined the appropriate time to introduce programming languages into a curriculum. They found that implementing the coding language “in the late primary education (6th grade) significantly accelerated the learning curve” but that “this was not the case in 2nd grade” (p. 296). Implementing an education technology into the wrong type of classroom can have negative effects that are not the fault of the technology. Another example of a technology being misunderstood and misused are smartphones in classrooms. For a long time smartphones were considered a distraction and were not seen as a useful tool for teaching. However, as teachers begin to recognize the potential of smartphones and new methods of using them for education, their effectiveness has increased. 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 found that some of the applications used most often by the teachers did not have a strong impact on learning (p. 27). Despite those specific applications not having an impact on learning, the researchers also found that “mobile technology is linked with the improvement of students' engagement to learning” (p. 27). Again, the lack of the technology’s impact on the learning environment should not always be attributed to the technology but rather the barriers that occur during the implementation process.

The linear handoff model shown in Figure 1 on page 3 illustrates the ideal process for educational technology implementation as the current system allows. The technology should pass from engineer to administration to the teachers to the students, without any reduction in the effectiveness of the technology in the classroom. However, as discussed above, there are many other social factors that affect the groups involved in the implementation process. Barriers can arise because of the social factors, and the impact of the technology can be affected. Therefore,

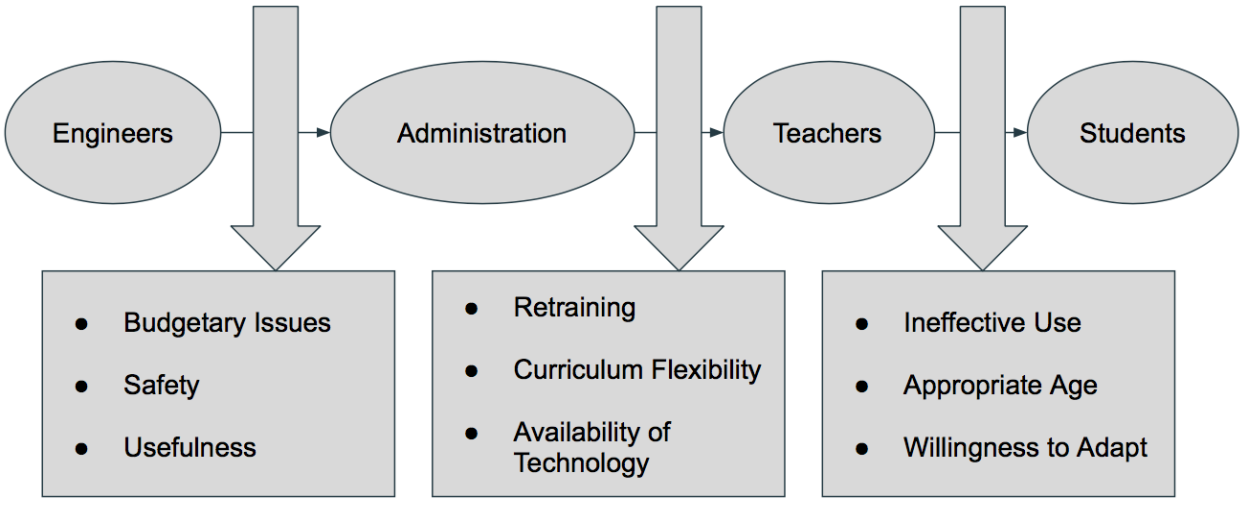

Figure 2: Revised Educational Technology Linear Handoff Model: Contains original flow of technology, but this version now includes the barriers that occur in between each step of the pathway (Billips, 2019).

shown above on page 8, is a revised version of the linear handoff model that includes the barriers that arise during the implementation process. This model shows how any of the barriers throughout the process has the potential to stop effective implementation. Identifying the barriers is the first step to solving the problems surrounding the educational technology implementation process.

POTENTIAL SOLUTIONS FOR OVERCOMING BARRIERS

Despite the many barriers that can arise during the implementation process, there have been successful introductions of educational technology into classrooms. Michael T. Luongo, a freelance writer who wrote a *New York Times* article in 2019 on educator's perceptions of technology use in the classroom, interviewed a professor who was able to effectively integrate new technology into his classroom and 'uses devices in the classroom to create a communication "back channel" with students' (para. 16). By communicating effectively with the students, the teacher was able to learn what their needs were and how to best use the technology in the classroom. Communication between the groups involved with the implementation process is important because in order for the social factors influencing each group to be understand, they must ne identified by all. There is some communication that happens in the current linear handoff model between the two groups involved in the handoff. For example, the administration might express concerns over the cost of a product to the engineer, and the engineer can then find ways of reducing the costs. However, this still does not solve all of the issues because if the engineer is not also talking to the teachers and the students, then the changes may not address the issues those groups are experiencing.

The ability of all the groups involved in the implementation process to actively communicate throughout is imperative to the success of the technology. If communication does

not occur, the barriers described above will occur, and the technology will not be effectively implemented. There has already been more active communication between groups, especially between engineers and the other three groups. Engineers are communicating with administration and teachers by stressing the importance of certain topics of education that involve technology. Jennifer Buelin, 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, used the 14 Grand Challenges for Engineering in the 21st century, as stated by the National Academy of Engineering, to discover what teachers thought were the most appropriate challenges for curriculums to focus on for kindergarten through high school (K-12) students (p. 47). Because of their communication, the engineers were able to discover that topics such as Preventing Nuclear Terror and Secure Cyberspace "were not deemed as important to K–12 technology education as other challenges were" (p. 49). With this new knowledge, the engineers can focus their efforts on designing educational technology for topics like solar energy, clean drinking water, or any other subject that the teachers and administration consider important for their students to learn. Active communication between those three groups led to overcoming some of the barriers in the implementation process, and highlights the importance of communication in the effectiveness of technology implementation.

The model shown in Figure 1 is based on the linear handoff model and it illustrates the implementation process as it currently functions, but as described above, there are many issues with this model that lead to the barriers shown in Figure 2. In order for the implementation process to be effective, there has to be communication amongst all of the groups with the focus being on improving the educational experience. The linear handoff model does not allow for this

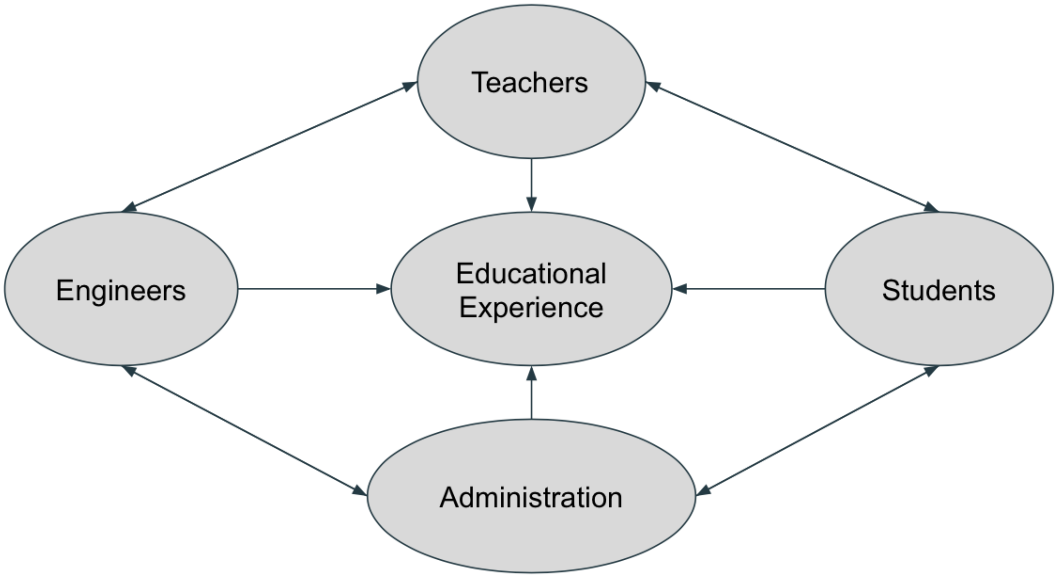

Figure 3: Social Construction Model for Creating the Educational Experience: Relationships among groups involved in the implementation process should incorporate communication to better influence the educational experience (Billips, 2020).

communication to occur, so another model is required to illustrate how the implementation process should work. Shown above in Figure 3 is a model based on the Social Construction of Technology model. In this model, all of the stakeholder groups are in communication with one another, expressing their desires and concerns regarding the educational technology being developed and implemented. The goal of all the groups, improving the educational experience, is shown as the central point of the model with each group having equal influence. While the communication between the groups does not necessarily mean that all of the concerns will be addressed and solved, they will at least be heard and can then be considered. There will still be negotiations between the groups and necessary compromises in order for the educational technology to be fully implemented. The administration will still have a budget, the teachers will still need training, and the engineers will still be looking to make a profit, but these social factors can be overcome if the implementation process is open amongst all of the groups involved.

THE FUTURE OF EDUCATIONAL TECHNOLOGY

Educational technology is becoming more crucial for the classroom as the world shifts towards a technology centered society. In their 2017 report for the Brookings Institute, Mark Muro, Sifan Liu, Jacob Whiton, and Siddharth Kulkarni, all from the Metropolitan Policy Program, analyzed the "change in the digital content of 545 occupations covering 90 percent of the U.S. workforce in all industries since 2001" (para. 2). They found that "between 2002 and 2016, the shares of U.S. jobs that require substantial digital knowledge rose rapidly" (para. 4). The use of digital tools and technology are becoming necessary for almost all areas of the workforce, and familiarity with technology is crucial. Having students begin to interact with technology in an effective way is an important step for preparing them for the real world, and improving the implementation process will be critical for that success. The first step has been discussed above, which is improving the communication between the groups involved in the process. This will allow the issues and concerns from each group to be heard and have influence on the educational experience. However, according to J. Michael Spector, the former editor of Educational Technology Research & Development for over 15 years, the need for improvement in the educational technology field is relevant and urgent. In his 2020 article, he stated that "we can do better as educators and educational technology researchers" (p. 3). There still needs to be communication channels developed for the necessary conversations to occur. Engineers might have a hard time communicating with the teachers and students if the current system allows administration to prevent communication. Establishing lines of communication between all groups will need to occur if the implementation process is to be improved.

WORKS CITED

Billips, P. (2019). *Initial educational technology linear handoff model*. [Figure 1]. *STS Research Paper: Problems with the Educational Technology Implementation Process* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va. Adapted from "Conceptual Frameworks" by B. Carlson, on October 24

Billips, P. (2019). *Revised educational technology linear handoff model.* [Figure 2]. *STS Research Paper: Problems with the Educational Technology Implementation Process* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va.

Billips, P. (2020). *Social construction model for creating the educational experience.* [Figure 3]. *STS Research Paper: Problems with the Educational Technology Implementation Process* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va. Adapted from "Conceptual Frameworks" by B. Carlson, on October 24

Buelin, J., Clark, A. C., & Ernst, J. V. (2016). Engineering's grand challenges: Priorities and integration recommendations for technology education curriculum development. *Journal of Technology Education*, 28(1), 37–52. Retrieved from https://eric.ed.gov/?id=EJ1139466

Butzin, S. M. (2001). Using instructional technology in transformed learning environments. *Journal of Research on Computing in Education*, 33(4), 367–373. https://doi.org/10.1080/08886504.2001.10782321

Carver, L. B. (2016). Teacher perception of barriers and benefits in K-12 technology usage. *Turkish Online Journal of Educational Technology - TOJET*, 15(1), 110–116. Retrieved from https://eric.ed.gov/?id=EJ1086185

Domingo, M. G., & Garganté, A. B. (2016). Exploring the use of educational technology in primary education: Teachers' perception of mobile technology learning impacts and applications' use in the classroom. *Computers in Human Behavior*, 56, 21–28. https://doi.org/10.1016/j.chb.2015.11.023

Johnson, D. (2012). Stretching your technology dollar. *The Resourceful School*, 69(4), 30–33. Retrieved from http://www.ascd.org/publications/educational-leadership/dec11/vol69/num04/Stretching-Your-Technology-Dollar.aspx

Jones, E., Michael, S., & Sittampalam, G. S. (2004). Basics of assay equipment and instrumentation for high throughput screening. In G. S. Sittampalam, A. Grossman, K. Brimacombe, M. Arkin, D. Auld, C. Austin, … X. Xu (Eds.), *Assay Guidance Manual*. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK92014/

Kulkarni, M. M., Sifan Liu, Jacob Whiton, and Siddharth. (2017, November 15). Digitalization and the american workforce. *Brookings*. https://www.brookings.edu/research/digitalization-and-the-american-workforce/

Lattie, E. G., Lipson, S. K., & Eisenberg, D. (2019). Technology and college student mental health: Challenges and opportunities. *Frontiers in Psychiatry*, *10*. https://doi.org/10.3389/fpsyt.2019.00246

Liu, F., Ritzhaupt, A. D., Dawson, K., & Barron, A. E. (2017). Explaining technology integration in K-12 classrooms: A multilevel path analysis model. *Educational Technology Research and Development*, 65(4), 795–813. https://doi.org/10.1007/s11423-016-9487-9

Luongo, M. T. (2019, December 11). Screens in the classroom: Tool or temptation? *The New York Times*. Retrieved from https://www.nytimes.com/2019/12/11/education/screens-classroom-tool-temptation.html

Moreno-León, J., Robles, G., & Román-González, M. (2016). Code to learn: Where does it belong in the K-12 curriculum? *Journal of Information Technology Education: Research*, 15, 283-303. Retrieved from http://www.informingscience.org/Publications/3521

Pinch, T., & Bijker, W. (1984). The social construction of facts and artefacts: Or how the social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science,* 14(3), 399-441. Retrieved from www.jstor.org/stable/285355

Spector, J. M. (2020, January 14). Remarks on progress in educational technology. *Educational Technology Research and Development*. Retrieved from https://doi.org/10.1007/s11423-020-09736-x

Wong, A. (2018, October 30). Why millions of teens can't finish their homework. *The Atlantic*. Retrieved from https://www.theatlantic.com/education/archive/2018/10/lacking-internet-millions-teens-cant-do-homework/574402/

BIBLIOGRAPHY

Berg, B., Cortazar, B., Tseng, D., Ozkan, H., Feng, S., Wei, Q., … Ozcan, A. (2015). Cellphone-based hand-held microplate reader for point-of-care testing of enzyme-linked immunosorbent assays. *ACS Nano*, 9(8), 7857–7866. https://doi.org/10.1021/acsnano.5b03203

Billips, P. (2019). *Gantt Chart* [Figure 1] *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va. Adapted from "Conceptual Frameworks" by B. Carlson, on October 24

Billips, P. (2019). *Initial Educational Technology Linear Handoff Model*. [Figure 3]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va. Adapted from "Conceptual Frameworks" by B. Carlson, on October 24

Billips, P. (2019). *Revised Educational Technology Linear Handoff Model.* [Figure 4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va.

Billips, P. (2019). *Full Network of the Educational Technology Implementation Process* [Figure 5]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va.

Buelin, J., Clark, A. C., & Ernst, J. V. (2016). Engineering's grand challenges: Priorities and integration recommendations for technology education curriculum development. *Journal of Technology Education*, 28(1), 37–52. Retrieved from https://eric.ed.gov/?id=EJ1139466

Butzin, S. M. (2001). Using instructional technology in transformed learning environments. *Journal of Research on Computing in Education*, 33(4), 367–373. https://doi.org/10.1080/08886504.2001.10782321

Carver, L. B. (2016). Teacher perception of barriers and benefits in K-12 technology usage. *Turkish Online Journal of Educational Technology - TOJET*, 15(1), 110–116. Retrieved from https://eric.ed.gov/?id=EJ1086185

Chavez, M., Ho, J., & Tan, C. (2017). Reproducibility of high-throughput plate-reader experiments in synthetic biology. *ACS Synthetic Biology*, 6(2), 375–380. https://doi.org/10.1021/acssynbio.6b00198

Collins, F. S., & Tabak, L. A. (2014). Policy: NIH plans to enhance reproducibility. *Nature News*, 505(7485), 612. https://doi.org/10.1038/505612a

Domingo, M. G., & Garganté, A. B. (2016). Exploring the use of educational technology in primary education: Teachers' perception of mobile technology learning impacts and

applications' use in the classroom. *Computers in Human Behavior*, 56, 21–28. https://doi.org/10.1016/j.chb.2015.11.023

Jensen, P. A., Dougherty, B. V., Moutinho, T. J., & Papin, J. A. (2015). Miniaturized plate readers for low-cost, high-throughput phenotypic screening. *Jala (Charlottesville, Va.)*, 20(1), 51–55. https://doi.org/10.1177/2211068214555414

Johnson, D. (2012). Stretching your technology dollar. *The Resourceful School*, 69(4), 30–33. Retrieved from http://www.ascd.org/publications/educational-leadership/dec11/vol69/num04/Stretching-Your-Technology-Dollar.aspx

Jones, E., Michael, S., & Sittampalam, G. S. (2004). Basics of assay equipment and instrumentation for high throughput screening. In G. S. Sittampalam, A. Grossman, K. Brimacombe, M. Arkin, D. Auld, C. Austin, … X. Xu (Eds.), *Assay Guidance Manual*. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK92014/

Kulkarni, M. M., Sifan Liu, Jacob Whiton, and Siddharth. (2017, November 15). Digitalization and the american workforce. *Brookings*. https://www.brookings.edu/research/digitalization-and-the-american-workforce/

Lattie, E. G., Lipson, S. K., & Eisenberg, D. (2019). Technology and college student mental health: Challenges and opportunities. *Frontiers in Psychiatry*, *10*. https://doi.org/10.3389/fpsyt.2019.00246

Liu, F., Ritzhaupt, A. D., Dawson, K., & Barron, A. E. (2017). Explaining technology integration in K-12 classrooms: A multilevel path analysis model. *Educational Technology Research and Development*, 65(4), 795–813. https://doi.org/10.1007/s11423-016-9487-9

Moreno-León, J., Robles, G., & Román-González, M. (2016). Code to learn: Where does it belong in the K-12 curriculum? *Journal of Information Technology Education: Research*, 15, 283-303. Retrieved from http://www.informingscience.org/Publications/3521

Pinch, T., & Bijker, W. (1984). The social construction of facts and artefacts: Or how the social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science*, 14(3), 399-441. Retrieved from www.jstor.org/stable/285355

Spector, J. M. (2020, January 14). Remarks on progress in educational technology. *Educational Technology Research and Development*. Retrieved from https://doi.org/10.1007/s11423-020-09736-x

VDOE :: The Standards & SOL-based Instructional Resources. (n.d.). Retrieved March 22, 2020, from http://www.doe.virginia.gov/testing/sol/standards_docs/

Wong, A. (2018, October 30). Why millions of teens can't finish their homework. *The Atlantic*. Retrieved from https://www.theatlantic.com/education/archive/2018/10/lacking-internet-millions-teens-cant-do-homework/574402/