Integrating Technology into Science Education

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Abstract

The technology behind science education has made significant advances in recent years. Microcomputer-Based Laboratories (MBL) or probeware has made experiments quicker and more efficient. MBL can help students understand scientific processes because they provide real-time data and measure variables that traditional tools do not detect. Interactive simulations also help students visualize complex scientific phenomenon. Programs like Molecular Dynamics Simulations (MDS), pHet, and virtual dissections allow students to explore inquiry-based lessons without the time and expense of setting up a lab. Immersive interfaces, such as augmented reality (AR), multi-user virtual environments (MUVE), and virtual reality, create visceral learning experiences for students. Increased immersion enhances student engagement and learning outcomes. Social media can teach students how to communicate and participate in the scientific community. Online resources often found on social media also are valuable resources for teachers to collaborate with peers.

Keywords: STEM, Education, Technology, Social Media, Augmented Reality, MUVE, Simulation, Web 2.0

Integrating Technology into Science Education

News stories seem to bombard Americans every day about how the educational system is failing to adequately teach science to the next generation (Umoh, 23). New technologies are seen as a solution to this problem. Unfortunately, the implementation of new technologies has been uneven at best. While no silver bullet exists to solve this crisis, rapid advances in technology have made significant changes to science education. This paper is an overview of the integration of recent technological innovations into science education on the topics: Microcomputer-Based Laboratories, interactive simulations, immersive interfaces, and social media.

Microcomputer-Based Laboratories (MBL)

The lab is one of the bedrocks of a science education classroom. MBL, also known as probeware or dataloggers, has made scientific labs more understandable for students and quicker to set up for instructors. MBL consists of sensors that can be linked to a computer to record real-time data (Tortosa, 2012). Examples of products available from Verner, one of the major probeware vendors, include accelerometers, CO_2 gas sensors, conductivity probes, light sensors, pH sensors, power amplifiers, temperature sensors, and UV sensors (Sensors, n.d.). While older forms of MBL required students to use a PC or laptop, newer probes may wirelessly link with smartphones, tablets, or Chromebooks (Sensors, n.d.). These sensors have transformed the science lab by allowing students to record data from a wide variety of scientific fields instantaneously.

Unlike traditional lab techniques that require students to graph results after an experiment has happened, data from MBL labs is presented immediately (Tortosa, 2012). MBL saves class time, allows for more extensive investigations and more discussion (Tortosa, 2012). Studies have found that when students view data from an experiment in real-time, they comprehend it more thoroughly (Tortosa, 2012). Probeware works well when teaching an inquiry-based learning lesson allowing students to have time to explore (Tortosa, 2012). Therefore, not only can MBL help students learn science but it can help students to develop strong collaborative skills (Tortosa, 2012).

For example, motion detectors would be useful in teaching a lesson about the velocity of objects given the variables distance and time. An example of a motion experiment used in physics classrooms is one where students time each other walking set distances. Students can calculate the average velocity of the walk by dividing the distance traveled by the time elapsed. A motion detector not only determines the average velocity the student moved, but it can show their instantaneous velocity and acceleration throughout the course in real-time. Students have more time to explore with MBL because they are not calculating every data point. They may adjust their walk by walking faster or slower to see how their actions change the graph. Thus, MBL can make mundane labs into highly engaging experiences.

Some instructors are reluctant to use MBL due to shrinking budgets and limited instructional time. A class may use probes once, whereas technological tools like Chromebooks can be used many times for several different subjects. Despite MBL's effectiveness, some students have difficulties operating the equipment and may be confused with the data provided by the probeware (Tortosa, 2012). Ultimately, teacher training with probeware is necessary for MCL's practical usage because these labs require thorough planning and strong classroom management (Tortosa, 2012). Science teachers may bypass the expense and time commitment of MBL by using computer-based simulations as a supplement and alternative to traditional labs.

Interactive Simulations and Models

Interactive simulations and models are useful tools to help students create conceptual models (Psycharis, 2016). Instructors often display models to help students visualize complex scientific concepts (Psycharis, 2016). Unlike conceptual models found in diagrams and videos, modern computational devices have a unique ability to create customizable simulations of natural processes (Kozma, 1991). Often, when presented a scientific concept, students are unable to think outside of the framework of the model that is taught (Psycharis, 2016). Because computational models are significantly more sophisticated than static models, students may learn a more precise schema of scientific concepts compared to that of traditional instruction.

Computer simulations of a scientific phenomenon can demonstrate variables that are unobservable or impossible to create in a laboratory setting (Moore, Chamberlain, Parson, & Perkins, 2014). While a traditional lab of electronic circuits may teach students how to create a circuit, simulations through programs like everycircuit.com allow students to visualize how the electric current flows through that circuit (Gryczka, Klementowicz, Sharrock, & Montclare, 2016). Moreover, while things at the atomic scale are impossible to see with current technology, computers can simulate how molecules interact.

Molecular Dynamics Simulations (MDS)

Molecular Dynamics Simulations (MDS), also known as Molecular Dynamics (MD), is a technology that simulates atomic and molecular behavior (Burkholder, Purser, & Cole, 2008) (Tinker & Xie, 2008). Recent increases in computational power have made what was once exclusive to high-level researchers available to low-level chemistry classes (Burkholder, Purser, & Cole, 2008). MDS are computer-generated models of atoms and molecules programmed to follow standard Newtonian laws (Burkholder, Purser, & Cole, 2008). For example, an instructor can put a water molecule simulation on a projector screen during a lecture while explaining Brownian motion (Burkholder, Purser, & Cole, 2008). Unlike traditional animations or videos found on the internet, MDS calculates the behavior of the atoms and molecules in real-time, allowing for each simulation to be an independent experiment (Burkholder, Purser, & Cole, 2008).

When students have time to tinker with MDS software, their experiments with the simulated molecular system allows them to discover scientific principles on their own (Tinker & Xie, 2008). Studies have shown that students learn better if they use MDS first to explore the concept before the teacher teaches the topic, then after the lesson as a review (Tinker & Xie, 2008). An instructor is necessary to provide scaffolding for experimentation, or students may not learn what they are supposed to (Burkholder, Purser, & Cole, 2008). The sheer complexity of the MDS simulations may overwhelm students (Tinker & Xie, 2008). Instructors using MDS should be cognizant of experiments that are excessively large and complex due to the computational limits of the computer running the program (Burkholder, Purser, & Cole, 2008). While the planning of inquiry-based labs with MDS may be overwhelming for some instructors, the benefits of increased student engagement and learning outcomes makes the simulation package worthwhile.

A free, open-source MDS is the Molecular Workbench (Tinker & Xie, 2008). However, this author’s attempt to install the program on his Windows 10 computer has been met with failure. The program is copyrighted 2004-2007 and does not seem to have been updated since. Another well-known educational MDS is ODYSSEY® which is available on Windows or Macs. The software package includes the concepts of Dispersion Forces and Miscibility of various substances in Methane and Water (Burkholder, Purser, & Cole, 2008). Unfortunately, ODYSSEY® is a proprietary software package that charges a license fee for its usage. Fortunately, educational simulations, like the website pHet, do not have this predicament.

pHet

The popular simulation program pHet was developed by the University of Colorado starting in 2002. A quick count on the pHet website shows 141 interactive simulations created with HTML5 available to the public as of the writing of this paper (2017). The subjects that pHet simulates include biology, chemistry, earth science, and math. These simulations are available for many different grade levels on multiple devices, including PCs, tablets, and Chromebooks. Each simulation is created by a diverse team of content, education, and interface design experts, along with experienced teachers and professional software developers" (Moore, Chamberlain, Parson, & Perkins, 2014). The design principles of pHet include interactivity, dynamic feedback, multiple representations, intuitive interfaces, real-world connections, challenges, games, and implicit scaffolding (Burkholder, Purser, & Cole, 2008). Thus, pHet simulations are designed to be educationally relevant to teachers and free for educators.

Teachers are encouraged to use these simulations in their classrooms in several ways. In a traditional lecture, instructors may use pHet like a lab demo by projecting the simulation on the screen (Moore, Chamberlain, Parson, & Perkins, 2014). Students may also explore the simulation on their own in inquiry style lessons with or without the guidance of worksheets (Moore, Chamberlain, Parson, & Perkins, 2014). While mathematically intensive science subjects such as chemistry and physics have many simulations in pHet, the memory-intensive subjects like anatomy are not present on the site. Fortunately, simulations exist that aid subjects like anatomy.

Virtual Dissections

Virtual dissections are a technological solution to some of anatomy instruction's largest drawbacks. Dissections of "real" specimens have significant disadvantages. Carolina Biological Supply Company, a major vendor of preserved specimens as of the writing of this paper, charges $7.90 for a bullfrog, $20.00 for a rat, $26.00 for a pig, and $108.00 for a cat (Carolina, n.d.). This cost is exponentially higher in medical schools where the students perform dissections on human cadavers. Furthermore, safety concerns are of paramount importance in the classroom. The use of scalpels often worries instructors, disqualifying students with behavioral difficulties from participating.

Moreover, a significant number of students do not participate in dissections because they feel squeamish around the specimens or oppose dissections based on ethical or religious reasons (Hasan, 2011). In higher education, traditional dissections are impossible to perform in the growing field of distance education because these labs must be done in a proper facility. It is hoped that with virtual dissections, students may get the learning benefits of a traditional dissection without the mess, time commitment or cost.

Unfortunately, studies of the effectiveness of virtual dissections is mixed (Lombardi, Hicks, Thompson, & Marbach-Ad, 2014). Students that are exclusively taught with virtual dissections perform statistically worse on tests compared to those doing traditional dissections (Lombardi, Hicks, Thompson, & Marbach-Ad, 2014). Moreover, students performing virtual dissections showed significantly less enthusiasm for the subject compared to their conventionally educated counterparts (Lombardi, Hicks, Thompson, & Marbach-Ad, 2014). While virtual dissections may accurately depict the location and the appearance of the parts of a specimen, they do not teach students "psychomotor dexterity, lexical enhancement and bioethical values"

(Hasan, 2011). As accurate as virtual dissections may be, they will never be as immersive as the real thing.

While virtual dissections are unlikely to replace traditional ones, they are an invaluable tool when used as a supplement. Instead of coming in for tutorials to study a specimen, students may study virtual organisms at home. Due to decreased costs, instructors can offer students a larger variety of organisms giving students a better grasp of comparative anatomy. While no simulation can completely replicate the dissection experience, engineers are bridging this gap with technologies like virtual reality.

Immersive Interfaces

Immersive experiences are defined by the degree that users feel they are “participating in a comprehensive, realistic experience” (Dede C. , 2009). Well designed experiences change a student’s perspective on a situation (Dede C. , 2009). Instead of being lectured about how natural selection works, students may play interactive games simulating evolution. One simulation found at biologycorner.com puts students in the role of a bird trying to eat different colored moths (biologycorner.com, n.d.). When played behind a dark background, lighter moths are eaten up at a rate faster than those that are dark. Over time, the percentage of dark moths rises, while the lighter moths slowly disappear. While the game is not a state-of-the-art three-dimensional game, it is considered an immersive experience because of the realism of the simulation.

Moreover, standard classrooms often teach subjects outside of its real-world context (Dede C. , 2009). Teaching medical students about the use of antibiotics in a lecture room is different from teaching them to administer the lifesaving medicine in the same room as a sick patient. While traditional institutions of learning have been slow to adopt immersive learning experiences, the military and the corporate sector have simulators from topics ranging from flight to that of surgery (Dede C. , 2009). One immersive interface is augmented reality.

Augmented Reality (AR)

Augmented reality (AR) is a technology where users with smartphones or specialized glasses see virtual images overlaying objects in the real world (Billinghurst & Dünser, 2012). One of the most well-known examples of AR is the popular app, Pokémon Go. (Gryczka, Klementowicz, Sharrock, & Montclare, 2016). In this game, players with their phones can find virtual Pokémon placed in real-world locations and catch them. Non-game versions of AR include Google Glass and Microsoft HoloLens (Gryczka, Klementowicz, Sharrock, & Montclare, 2016). AR is considered a technology in its infancy. Some experts predict that by 2030, students "will be routinely building AR educational content" (Billinghurst & Dünser, 2012).

Google Sky Map is an augmented reality app of the night sky, useful for Astronomy classes. Users with Google Sky Map use their phone to look at the night sky to see the name of the stars, constellations, planets, and galaxies (Smith, 2008). Students may search for a stellar object, like Mars, and Google Sky Map will point users to its exact location. This app is of particular use for classrooms because school takes place during the day. It also is useful in city environments that have too much light to see many stars.

One experiment done with AR has been done in Taiwan with a virtual butterfly garden (Tarng, Ou, Yu, Liou, & Liou, 2015). Taiwan once was called the "Kingdom of Butterflies" because it had the largest variety of butterflies (over 400 species) in the world (Tarng, Ou, Yu, Liou, & Liou, 2015). The loss of habitat and the misuse of pesticides have endangered the butterflies on the island (Tarng, Ou, Yu, Liou, & Liou, 2015). These insects play a significant role in Taiwan’s educational curriculum, and many school campuses have gardens to help attract and protect them (Tarng, Ou, Yu, Liou, & Liou, 2015).

An augmented reality system was developed at an elementary school with a combination of QR codes and wireless networks (Tarng, Ou, Yu, Liou, & Liou, 2015). Part of this application’s function was to help students identify the taxonomical status of the butterflies, the plants they feed on, and their predators. (Tarng, Ou, Yu, Liou, & Liou, 2015). This application also allowed students to “breed virtual butterflies” allowing them to observe butterfly life cycles (Tarng, Ou, Yu, Liou, & Liou, 2015). These environments also had virtual predators simulating food-chains (Tarng, Ou, Yu, Liou, & Liou, 2015). Surveys of students using the system showed high levels of engagement (Tarng, Ou, Yu, Liou, & Liou, 2015). Unfortunately, augmented reality is limited to the location of a user. Conversely, virtual, three-dimensional, worlds are not limited by a person’s location.

Multi-User Virtual Environments (MUVE)

Multi-User Virtual Environments (MUVE) also known as Multi-User Virtual Worlds (MUVW) are simulated 3D locations that allow participants to interact with each other and virtual objects (Dede & Barab, 2009). People who play video games such as World of Warcraft or Second Life are familiar with this type of environment. Users are represented through avatars which are “graphical representations of participants” (Dede & Barab, 2009). In the MUVE, users may interact with objects in the virtual world to participate in “collaborative learning activities” (Dede & Barab, 2009). Popular science MUVE include Quest Atlantis, Active Worlds, River City, EcoMUVE, Open Wonderland, and SimLambia (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017).

MUVE have several advantages and disadvantages. Instructors and students in virtual environments may perform experiments that in the real world would be constricted space, size, cost and safety. (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017). Moreover, these virtual environments may help struggling students step “out of their real-world identity” into the frame of reference of someone like a famous scientist (Dede C. , 2009). Distance education classes may use MUVE, so students do not feel that their class is an impersonal “window based environment” (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017). Virtual environments give students that are separated geographically “incentives for socialization and collaboration” (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017). However, MUVE’s require computers with modern graphics cards, which can be pricey. They also have a “steep learning curve,” especially for non-gamers (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017). Despite these disadvantages, MUVE, when used correctly, increases student engagement. (Pellas, Kazanidis, Konstantinou, & Georgiou, 2017).

Examples of educational MUVE include River City and EcoMUVE. In River City, groups of three to four students explore a city from the 19th-century that is affected by an epidemic (Dede C. , 2009). Students must interact with the virtual townspeople of the town to discover the source of the outbreak. In EcoMUVE, students explore a pond environment simulation for two virtual weeks (Metcalf, Kamarainen, Tutwiler, Grotzer, & Dede, 2011). After a few days in the simulation, the fish die, and students must work in teams to discover why (Metcalf, Kamarainen, Tutwiler, Grotzer, & Dede, 2011). Future research in visually immersive virtual reality may be a way to make MUVE even more immersive.

Future possibilities with Visually Immersive Virtual Reality

Visually Immersive Virtual Reality (VIVR) uses displays that “provide the user with the ability to look in most directions and see the virtual environment” (Jacobson, 2011). Digital domes are a form of VIVR in which video displays encompass an entire domed room (Jacobson, 2011). Planetariums are the original versions of digital domes. These domed screens can be adapted to show three-dimensional video games. A study was done with the educational video game, Gates of Horus, has shown that students who play the game with a digital dome perform statistically better on tests over the information in the game, compared to those who play it the game with a traditional screen (Jacobson, 2011).

While space and price considerations make the regular use of digital domes prohibitive, the widespread adoption of 3D virtual reality headsets like the Oculus Rift or Google Cardboard may make VIVR more affordable for educators. While visually immersive virtual reality remains a nascent technology that can take students to fictional worlds, social media gives students opportunities to interact with the real world outside of the classroom.

Social Media

Social media can teach students how to collaborate with the outside world. According to the Pew Research Center’s Internet & American Life Project, “92% of teens ages 13–17 use the Internet daily, 76% use social media sites and 71% say they use more than one social media application” (as cited by Craig-Hare, Rowland, Ault, & Ellis, 2017). Students now have access to a vast quantity of scientific information outside the classroom. With social media, students can communicate not only with friends and family but with individuals from all over the globe with a passion for science (Craig-Hare, Rowland, Ault, & Ellis, 2017). Rather than just reading about the jungles, a student can Skype a naturalist that works in the Amazon rainforest. Unfortunately, these technologies have also given students access to exaggerated and false information. While the public has access to the publications from the top climate scientists, it also can access the highly distorted arguments of global warming deniers. To provide students a proper science education, teachers must instruct students on how to interpret the data seen online critically. Furthermore, students must learn how to articulate their views.

Teaching Scientific Discussion with Social Media

While many people use social media to discuss trivial topics, users may also engage in high-level scientific discussion online. A 2007 survey of bioinformatic scientists found that “77% of life scientists participated in some type of social media to advance their science, 50% said that social media was beneficial to sharing ideas with colleagues and 85% indicated that social media influenced their decision-making” (as cited by Craig-Hare, Rowland, Ault, & Ellis, 2017). Because high-level scientific discussion frequently happens online, social media is a highly appropriate place to teach students how to discuss science. Learning how to debate scientific issues online not only promotes STEM literacy, but it teaches them “to be part of an educated citizenry and active participants in civil discussions of issues central to our democracy” (Craig-Hare, Rowland, Ault, & Ellis, 2017).

Online resources used to help teach students argumentation include the Web-based Inquiry Science Environment (WISE) and the Cognitive Apprenticeship Web-based Argumentation System (Craig-Hare, Rowland, Ault, & Ellis, 2017). In the multi-player game, Reason Racer, students participate in an online discussion about a scientific topic (Craig-Hare, Rowland, Ault, & Ellis, 2017). In the final stage of the game, students must discuss whether to “accept, reject or withhold judgment on the claim being made by the article in the scenario under study.” (Craig-Hare, Rowland, Ault, & Ellis, 2017). When students feel comfortable discussing scientific topics, teachers may encourage them to use traditional social media to allow students to test their skills with the outside world.

While sites like Twitter provide students the ability to discuss topics with people across the world, the 280-character limit (up from 140 as of 2017) hinders a person’s ability to articulate nuance (Craig-Hare, Rowland, Ault, & Ellis, 2017). Students can participate in more sophisticated discussions on the blogs of prominent scientists. When introducing social media to the classroom, teachers must establish “ground rules with regard to the creation and/or use of social media accounts can help facilitate school-based usage and ensure that school district policies and behavioral expectations are followed.” (Craig-Hare, Rowland, Ault, & Ellis, 2017). A good set of standards for social media usage comes from The International Society for Technology in Education (ISTE). Social media can not only teach students to discuss science, but it also allows them to contribute to scientific research.

Citizen Science with iNaturalist

Social media has made a tremendous impact in the field of taxonomy with programs like iNaturalist. Much of the world’s biodiversity has been documented by amateurs (Merenlender, Crall, Drill, Prysby, & Ballard, 2016). The crowdsourcing site, iNaturalist, has made it easier for people to participate in zoological research. Using the iNaturalist smartphone app, users take a picture of an organism. The photo is uploaded along with the location and the time it was taken into “big databases used by scientists, park experts, watershed managers and others” (Said, 2014). iNaturalist has been described as “The Facebook of Biology” because it allows people to communicate with other users (Wittmann, n.d.). As of the writing of this paper, almost 6.8 million observations of over 128,000 species have been made on the site (California Academy of Sciences, n.d.).

“Citizen science” projects like iNaturalist have attracted privacy concerns, especially for minors (Bowser, Wiggins, Shanley, Preece, & Henderson, 2014). In the United States, the Children’s Online Privacy Protection Act (COPPA) places heavy restrictions on programs like iNaturalist to protect minors (Bowser, Wiggins, Shanley, Preece, & Henderson, 2014). One potential violation of the privacy of students is the location data recorded with every observation on iNaturalist. People with harmful intentions may use this data to extract the personal information of users (Bowser, Wiggins, Shanley, Preece, & Henderson, 2014). While iNaturalist has safeguards that may hide or obscure the location of observations, these are not enabled by default. Moreover, iNaturalist’s communication functions are problematic because the site is unable to monitor the discussions of its users. To address privacy concerns, the site requires that users must be at last 13 to participate (Bowser, Wiggins, Shanley, Preece, & Henderson, 2014). These heavy restrictions have limited the number of educational materials available for educators to use.

While the organization running iNaturalist has not created an educational curriculum, several users have created unofficial resources for educators. The teacher Julie Wittmann has a blog about how she has integrated iNaturalist into her high school classroom (Wittmann, n.d.). On the first day of the project, she presents a short tutorial about iNaturalist is, and students create iNaturalist accounts. Students have four weeks in the spring to use the iNaturalist app to document a specified amount of flora and fauna. During this time, class time is filled with “lessons with additional PowerPoint lectures, short video clips, vocabulary-building, small group activities, and guest speaker presentations” (Wittmann, n.d.). At the end of the project, “winners” are selected from each class period for students who go above and beyond in their observations (Wittmann, n.d.).

Teachers thinking about implementing this program in their classroom must keep a close watch in their class. Teachers are encouraged to make at least 20 to 30 observations on their own to get the feel of how the site works (California Academy of Sciences, n.d.). Unfortunately, teachers must keep an eye out for students by downloading images of organisms off the internet rather than doing the project themselves (Wittmann, n.d.). Students often feel like they are using iNaturalist “under duress” (California Academy of Sciences, n.d.). Inaccurate data not only harms the student, but it hurts real world scientific research.

Despite the drawbacks of teaching with social media, science continues to be discussed online, and research continues to be done with sites like iNaturalist. As more digital natives enter the scientific community, one can expect social media to play an even more significant role in scientific research in the future. Students need to learn to use these tools responsibly. Thus, science instruction needs to include social media training. While science has taken full advantage of the collaborative nature of the internet, so have teachers.

Additional Online Tools for Teachers

In addition to supporting student learning, the internet may help teachers to collaborate with other colleagues. The internet provides teachers a plethora of lesson plans, and social media allows teachers to communicate with subject matter experts (Craig-Hare, Rowland, Ault, & Ellis, 2017). It also may “bring like-minded educators together to share ideas, brainstorm, and problem-solve” (Craig-Hare, Rowland, Ault, & Ellis, 2017). In addition to numerous Facebook groups, science teachers can collaborate on the discussion board of the National Science Teachers Association’s (NSTA) website.

Moreover, many high-profile institutes have provided a wealth of information for science teachers to augment their curriculum. Biology teachers have access to the educational section of the Howard Hughes Medical Institute (HHMI) found at https://www.hhmi.org/education. The site has a wide range of videos and lessons on genetics and evolution. NASA, always a pioneer in educating students, has dedicated a large number of resources online to help educators at https://www.nasa.gov/education/. Not only does the agency have resources on space and aerospace, but it has support for mathematics, physical science, and life sciences. Another national institution with an extensive education department would be the National Oceanic and Atmospheric Administration (NOAA) found at http://www.noaa.gov/education. Finally, the Smithsonian has dedicated a large number of resources to help educators at http://www.smithsonianeducation.org/educators/events/online_events.html. It is a relief for many teachers, including this author, to have an alternative to in-services to learn best practices and new strategies to teach students.

Conclusion

Much technological progress has been made in the last generation to advance science education. Laboratory experiments are quicker and more efficient with Microcomputer-Based Laboratories. Simulations help students create proper models of complex scientific topics. Immersive interfaces such as augmented reality provide visceral learning experiences for students. Social media allows students to interact with the scientific community as a whole. While these technologies will be vital to educate the leaders of tomorrow, it is critical to remember without dedicated educators, none of these techniques will work to their potential. While technology cannot replace the passion that an educator has for science, it can certainly make it easier for teachers to teach it.

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I think this was your strongest paper of all three because you were able to really articulate yourself and the research you doncucted. Although I have minimal knowledge in the topic, I was able to follow along and tie each section together. There were a few punctuation issues (commas) and a few known overused words (effective) that I would suggest paying attention to when you do your final read. Great job