Modeling and Simulation Challenge Problems in High School Classrooms and Internships: Lessons Learned

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ABSTRACT

The use of modeling and simulation is widespread across scientific and engineering disciplines and all branches of the United States military utilize modeling and simulation for training, testing, and developing next generation capabilities. Despite this reality, modeling and simulation is largely absent from high school classrooms. Through the use of game-based technology challenges, our team has implemented three years of internship experiences and developed high school M&S content as a way to get learner buy-in and engage students. The Air Force Research Laboratory's Gaming Research Integration for Learning Laboratory has hosted educators, student interns, and mentors since 2011. In this paper we describe the history and evolution of this program which introduces high school students to modeling and simulation, problem-based learning, and provides models of the types of problem-solving capabilities required for working in the defense industry. We review and discuss observations from summer internships and high school classrooms and present anecdotal evidence on student outcomes. Further, we discuss lessons learned with regard to student motivation and teacher education and training as well as future measurement of the program's effectiveness. Observations made to-date suggest that for students who have already achieved academic excellence in high school, substantial gains may be made through short-term internships such as a summer appointment. For students at risk of excluding themselves from science and technology-related career paths, modeling and simulation content has potential to motivate students to address any gaps in their completion of prerequisite courses they will need to move forward. Successful integration of modeling and simulation content within a classroom requires a substantial time investment in the teaching staff but through consistent support, teachers are able to develop the baseline level of comfort and proficiency with the content to support the students in their exploration of the technologies.

ABOUT THE PRIMARY AUTHORS

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INTRODUCTION

The need to prepare and inspire the next generation of science, technology, engineering, and mathematics (STEM) graduates is well documented. This need is articulated in everything ranging from executive-level reports to strategic plans published by various branches of the US military (e.g., Executive Office of the President, 2012; National Research Council, 2010; President's Council of Advisors on Science and Technology, 2010; United States Air Force Chief Scientist, 2010). Government and military reports not only identify the need for an appropriately skilled workforce, but also go further to identify priority areas that include K-12 STEM teacher education, engagement, undergraduate STEM education, and further involvement of groups typically underrepresented within STEM career fields (National Science and Technology Council, 2013). The current United States Air Force's (USAF) STEM programs highlight the investment being made in the future Department of Defense (DoD) workforce. There are numerous vehicles through which students, ranging in age and experience, can participate in summer-long research and engineering opportunities, including the United States Air Force Academy Center for K-12 STEM Outreach and Research, the Wright Scholar Research Assistant Program out of Wright Patterson Air Force Base (WPAFB) in Dayton, Ohio, the Science, Mathematics and Research for Transformation Scholarship for Service Program, and opportunities in collaboration with the Oak Ridge Institute for Science and Education. In this paper we summarize efforts conducted in collaboration with one of these programs, the Wright Scholar Research Assistant Program at WPAFB.

The Air Force Research Laboratory's (AFRL) Gaming Research Integration for Learning Laboratory (GRILL), part of the 711th Human Performance Wing's Warfighter Readiness Research Division (AFRL, 711 HPW/RHA) located at WPAFB in Dayton, Ohio, focuses on the integration of game-based technology in USAF training environments. By leveraging these technologies, the AFRL investigates affordable methods and approaches to complement and supplement the training capabilities being researched in larger footprint, high-fidelity training systems. The GRILL has expanded their application of game-based technologies in recent years to include STEM education and mentoring opportunities. Specifically, the GRILL's goal is to leverage game-based technology to provide engaging learning opportunities for students both in internship and classroom settings and to provide educators with opportunities to become familiar with the technology and observe the manner in which the USAF is leveraging them to solve problems for the warfighter. The GRILL aims to utilize the team's knowledge and capabilities to recruit more students into the STEM pipeline and to prepare and retain the largest numbers possible to strengthen the next generation STEM workforce.

The use of modeling and simulation (M&S) is widespread across scientific and engineering disciplines. All branches of the United States military utilize M&S for training, testing, and developing next generation capabilities. Despite this reality, M&S has been largely absent from high school classrooms. Integration of M&S content at the high school level introduces students to powerful tools while enabling problem-based learning in the classroom. Through the use of game-based technology challenges, our team has identified a way to get learner buy-in and engage students. The internship described in this paper provides a learner-centered environment in which teachers and mentors act to guide students, encouraging them to reflect on their learning with the ultimate goal of transitioning into self-monitoring, independent learners (Flynn, Mesibov, Vermette & Smith, 2014). Additionally, the high school M&S content resulting from these internships are materials that support the strategies of the 21st century classroom, with a focus on problem-solving, active learner engagement, and the ability for students to work in small, heterogeneous groups at a pace they determine (Voogt & Roblin, 2010). In the following sections we summarize the history of the GRILL STEM program and present observations and lessons learned during the previous three years. We include anecdotal evidence observed to-date regarding the impact of the M&S content on the experience of students and teachers, citing examples from both summer internships and high school classrooms.

GRILL STEM PROGRAM HISTORY

At the time we prepared this manuscript, the GRILL had executed three 9-week summer efforts during which teachers, students, and mentors were co-located at the GRILL. During the summer of 2011, the GRILL hosted eight high school students (seven from the Wright Scholar Research Assistant Program), and one high school math educator. A team of five mentors were assigned to work with the students, including three behavioral scientists and two software engineers. The charter given to the team was to develop a capstone for a semester-long high school M&S course in which students would build a fire evacuation simulation using game-based technology. Students conducted hands-on evaluations of game engines in collaboration with the mentors, evaluating four game engines for their usability, the degree to which students were able to achieve success, and the availability of official and user-generated support resources/communities. The students were able to achieve the fire simulation in more than one game engine, which served to verify the feasibility of employing this type of task in a classroom setting with high school students. Ultimately, one engine was selected, and the students assisted in the creation of tutorials to serve as the basis of materials for the curriculum writing team. Following the summer effort's completion, the curriculum writing team continued their work to shape their materials and produce corresponding professional development and training materials for teachers. Within the first year following the content completion, the course was piloted in 11 school districts in the Dayton area (190 students in the first year of the course with more enrolled in subsequent years). The M&S course content was sponsored by the WPAFB Educational Outreach Office, and administered through the Dayton Regional STEM Center.

In 2012, the GRILL continued the development of STEM content, but instead of working on a capstone project for a full semester course, the team focused on the development of challenge problems, which are real world or authentic problems designed for high school students to address utilizing their STEM content skills. Challenge problems are intentionally designed to inspire new STEM skills as well as develop their conceptual understanding of high level science, technology, engineering and mathematics content. This type of challenge-based instruction is common in engineering educational settings (Berland et al., 2013; Berland, Allen, Crawford, Farmer, & Guerra, 2012). The team consisted of thirteen students through the Wright Scholar Research Assistant Program, three college student interns, seven high school educators, three behavior science mentors, and two software engineering mentors. The team employed the same approach as in year one, which is to have students work hands-on with the software tools in order to evaluate the state-of-the-art in game-based technologies for use in a classroom context. In this year, the content was expanded to include racing simulations and the use of M&S as related to biomedical and biological engineering. The result from the summer included a series of challenge problems which focused on introducing students not only to 3D modeling and the use of simulation, but also to live, virtual and constructive training capabilities. This content, referred to as Full Throttle STEM™ challenge problems, provided an opportunity for students to gain hands-on experience with both 3D modeling tools (e.g., Sketchup) and the integration of hardware. One of the projects the team tackled specifically involved the integration of data feeds from a radio control (RC) car into a game-engine. As with the prior year, students assisted in the development of tutorials for later use by educators. One addition to the program in this summer was the integration of in-depth programming activities undertaken by the students. Specifically, students worked with MATLAB and three freeware alternatives to assist in identifying the most cost-effective, user friendly option to utilize in a classroom setting. A second extension of the efforts included collaboration with a local racetrack, Eldora Speedway in Rossburg, Ohio. Students worked with representatives from Eldora to build a virtual representation of the racetrack that would enable patrons to view seating options via the Internet and to “walk” through the virtual representation of Eldora Speedway on the Internet.

In the summer of 2013, the team consisted of fifteen Wright Scholars, four college student interns, five high school educators, three behavioral science mentors, and three software engineering mentors. This team continued to refine and expand the Full Throttle STEM challenge problems and associated tutorials for teachers and students. As with the prior year, students worked with a customer to design a simulation-based capability for use in the real-world. Representatives from the US Air Force School of Aerospace Medicine (USAFSAM) defined requirements for a virtual implementation of an equipment placement/setup task for aeromedical evacuation trainees. Students built 3D models of approximately 50 pieces of medical equipment and imported the models into the game engine to enable users to configure a C-130 cargo area. The resulting simulation was handed off to USAFSAM representatives for use in allowing their trainees to explore the placement options for the various pieces of equipment within the aircraft. Another result from the summer included extensions to the Full Throttle STEM challenge problems, including additional written guides for use in classrooms. Students also explored the use of scanning technology to rapidly generate 3D models through the use of video game peripherals.

The evolution of students’ activities and the focus of content development occurring in the GRILL evolved over the years through interactions between teachers and GRILL mentors, but remained focused on introducing students to the technologies being employed for warfighter training research and those tools that would assist in the development of the problem-solving and other technical skills relevant to M&S and STEM career paths. Teachers, having worked directly with students over the course of the school year, had direct input regarding the activities that the students were ready to tackle. As a result, the complexity of the challenge problems has increased over the years. Students had demonstrated their ability to produce quality simulations through the use of game-based technologies. As a result, efforts such as the USAFSAM collaboration were targeted to align the activities with real-world use cases.

The observations and anecdotal evidence we present in later sections of this paper were made based on both students participating in summer internships and students interacting with the M&S content in their high school classroom (grades 9-12). The semester-long capstone project, as developed in the GRILL in 2011, was piloted in more than 11 schools throughout the Dayton area since 2011. The classroom observations reported in this paper were noted in the Tri-Village Local School District (LSD), a rural, economically disadvantaged school district in Ohio. Tri-Village LSD was one of the pilot schools for the M&S content, and the district has also implemented multiple challenge problems, as developed in the GRILL in 2012 and 2013, in their high school classrooms.

LESSONS LEARNED

In this section we highlight lessons learned and observations from the teacher, student, and mentors’ perspectives, based on both our experience working with the Wright Scholar Research Assistant Program and with teachers implementing this content in classrooms. It is worth noting that the Wright Scholar students are exceptional in academic achievement, as evidenced by their acceptance into this competitive internship. By working with students in high school classrooms as well, the team was able to make observations about the feasibility and experience of implementing M&S content over a wider range of student achievement levels.

First and foremost, we observed for three consecutive years that high school students from all levels of academic achievement are able to successfully generate solutions to complex problems using the full tool range of M&S tools, from 3D modeling software (e.g., Sketchup, 3ds Max® and Blender) to game engines (e.g., Source and Unity). Students working with these technologies are able to produce quality 3D models, import them into game engines, and assign physics and modify other parameters enabling users to interact with the objects within a game environment. Students successfully incorporated a variety of hardware and software into their solutions, customized for the purposes of each application.

Through the process of software evaluation, the unique constraints of an educational environment became evident. In the summer of 2011, four different game engines were evaluated for potential use in the fire evacuation

simulation. Quickly the team realized that some tools were significantly more user friendly than others. Further, the availability of large user communities, and therefore larger sources of online tutorials, provides additional support for students beyond that which teachers are able to provide, assuming the teachers are learning to use the technologies as well. Given the often fluid nature of the M&S tool range, this supplementary support can be paramount as a teacher may have little, no, or outdated knowledge surrounding specific software or processes.
With each software and hardware use, the team has had to consider affordability of the tools when selecting those for use in the content. Feasibility of schools attaining and successfully implementing the tools has been in the forefront of consideration throughout the history of the program and students are fully capable of carrying out the majority of steps involved in the process of tool evaluation.

The success that students are able to achieve through the use of these technologies does not come without challenges. The co-location of mentors and students throughout the summer helps to manage student frustration levels, allowing for intervention as needed to help students continue their progress. The management of team size is an important consideration and depends on the experience level of the team members. Seating capacity is entirely different than the capacity to manage and facilitate coordination within these types of team. A core set of mentors and teachers had served all three years and a small number of students were selected in 2012 and 2013 to serve as returning mentors, which helped to leverage lessons learned each year in terms of organization and facilitation of the tasks for teams of this size.

Although the internships last nine weeks, students split their time between working in the lab with the mentors and also attending lectures and other professional development activities around WPAFB. Accordingly, the nine-week period goes by quickly and much coordination is required to ensure maximum learning opportunities when the students are in the lab with the team. Given that the students and teachers work jointly on the supplemental tutorials for use in classrooms throughout their various projects, editing and version control is a challenge. Editing content generated by multiple authors with varying levels of writing experience requires careful attention. Splitting students into manageable teams across the different projects is no small feat, especially with the goal of ensuring that all students are challenged and working on projects of interest to them. Managing the administrative considerations related to the implementation of this type of program is worth noting, but the lessons learned we discuss from this point forward focus more on the instructional content. In the following sections we present observations and lessons learned related to student engagement and teacher training.

Student Engagement and Motivation

Students participating in GRILL internships over the summer through the Wright Scholar Research Assistant Program are often interested in a variety of career paths. As juniors and seniors in high school, they have some awareness of the focus of their discipline but are not aware of the ways in which M&S is applied in the discipline. Often a first reaction we see is along the lines of “Why am I assigned to a video gaming lab?” Up front efforts to educate students on M&S and awareness of its applications across science and engineering disciplines helps minimize the uncertainty and doubt that students have expressed in the beginning of their internship.

After three years of working with 3D modeling tools, game engines, and other tools such as RC cars, we have observed that these technologies can be both engaging and motivating to students. In some cases within the classroom settings, students who are even failing math are able to achieve success and be looked to by other students for assistance and guidance. According to their teachers, these students do not typically feel that way. Students are applying their newly formed outreach skills to their content areas. In one instance, a teacher reported to us about a student who took the initiative to find a mathematics tutor after realizing the value in sitting with someone he learns well from, He successfully brought up his grade by 34%. At one rural district implementing the M&S content, a prerequisite requirement of algebra II has led to a significant increase in student enrollment in higher level mathematics classes at earlier grade levels, even summer school enrollment, so that they meet the mathematics requirements to enroll in the M&S courses.

Additional aspects related to the delivery of instructional content using the game-based technology may impact the level of engagement. Whether in the context of an internship or classroom activities, the importance of real-world value/application cannot be over emphasized. The likelihood of buy-in to the project can be lessened if students perceive they do not have a say in the project design and modification. The need to provide an ill-defined problem to allow ownership by the learner has long been documented (e.g., Jonassen, 1997; Jonassen, 1999). Students reflecting on their summer internship in M&S reported that their buy-in is negatively impacted if the resulting product will sit on a shelf following its completion. Further, they reported that they will invest more effort in a project if the outcome will be utilized in the real-world. Experiences in which students were actively collaborating by creating and deciding the direction of the projects were reported to be preferred to situations in experiences in which students were testing what other individuals had written or working in isolation.

Additional outcomes were noted as a result of enlisting student help in developing materials for use by other students. Students reported making a transition from being a consumer of technology to a producer of it and developing an increased capability to research and identify potential tools to accomplish specific objectives. At times, the number and scope of tools had the potential to overwhelm students, but opportunities to elicit input from others helped mitigate this. Students reported that finding software tools to address a particular function was at times difficult but that they learned how to perform more precise internet searches to find more relevant options. At times, searches using the exact terms for what they wanted to do (functional search) did not return the best results, and they reported an improvement in their ability to search for applicable tools or content based on what they learned about other existing software. Teachers reported that this experience may have afforded students the opportunity to develop a better understanding of the tools and as a result they could draw appropriate conclusions and identify appropriate information to achieve their search objectives (Flynn, Mesibov, Vermette & Smith, 2014).

Both in the classroom and in internships, students encountered experiences highlighting the value of being flexible and the need to be resourceful. This was experienced firsthand by three students who took their M&S demonstration to a national conference. A hardware failure the day before departure to the conference resulted in much coordination to reconstitute their demonstration capability. Previously, according to their teacher, this type of situation would have been experienced as a failure. Support provided for students in such instances is critical to them understanding that this type of situation can be encountered and that contingency planning is important. The value of experiencing these failures, as reported by both students and educators, is in line with the failure-safe principle (Bielaczyc & Collins, 1999), which maintains that the extent to which failure is looked at as a learning opportunity can impact the extent to which participants will be allowed to explore and learn from failure. The M&S content has shown to provide opportunities for students to persevere in their efforts and troubleshoot in real-time.

Students experiencing immersion in the applied M&S problems report a better understanding that error, failure, and discovery are part of the development process, and that real-world problems and solutions are not always straight forward. Also, students reported value in the ability to "break things" or even go down the wrong path for some time. In this way, the internship experience allowed students to carry out and direct investigations without blame for failures as they learned about tools and their applications (Bielzczyc & Collins, 1999). Students noted that a simple interaction with others can aid in progress toward a particular goal, as others often have insights that they do not have prior to conversing. Opportunities to interact with team members, even in informal settings such as lunch outings, provided a low pressure environment to casually talk through problems. In some cases, these settings allowed others to share applicable examples and experiences they had encountered outside of the internship. These interaction opportunities, highly valued by the student interns, are noted within the educational literature as being an important aspect for a constructivist learning environment (Fosnot, 2005; O'Donnell, Hmelo-Silver, & Erkens, 2006). Students participating in internships reported that conversations helped team members discover that they had solutions to offer to others, when prior to the conversation they were unaware that their team member was even searching for a solution to a particular challenge.

Teachers implementing the M&S content in their districts report that students' desire to solve the provided STEM challenges intrinsically drives them to continue to work on the problem well beyond the school day, even if homework is not assigned. Students are engaged at a level well beyond what had previously been expected of them and they show interest in learning new skills and developing a working knowledge of STEM skills so that they can meet the challenges set before them. Students are sharing their experiences with their peers and their parents, including their excitement, frustration and accomplishments. The sharing of their work has corresponded with a greater number of students signing up for the courses. Implementation of prerequisite courses for M&S content eligibility in one rural district has led to an increase in student enrollment in higher level mathematics classes. Teachers report that students engaged in the challenge problems tend not to make excuses, persevere in their problem-solving, work to learn the content and skill set necessary to succeed in their given challenge and are eager to be given the next challenge problem. Students are expressing excitement about utilizing technology and engineering in their class work and therefore addressing the mathematics and science necessary to make it happen.

Teacher Support and Training

Through co-location, teachers and students have the opportunity to learn from engineering and science mentors. Teachers noted the value in having the opportunity to observe first-hand the skills that are needed to work in STEM career fields. They must then translate their experience into a strategy for equipping students with the skillset in the classroom environment. Some notable observations made by the teachers included the fact that, as an educator, one does not have to understand the answer or solution to undertake the endeavor. Additionally, they noted that learning to reach out to others is part of the solution and can be a sign of progress for a student. Educators reported that it was valuable to see firsthand that there may be real struggles throughout the course of a project. When a challenge is encountered, it is helpful to see examples of how individuals and teams decide to move forward. Students who can provide a long list of options they have tried and who can generate a list of optional next steps are exhibiting the type of problem-solving that they will be able to rely on in their later experiences, be it college or in the work force. Educators can support students by not providing all the answers regarding the way forward but rather by asking questions such as “to whom have you reached out” and “what other options do you think are worth pursuing?”

As noted by the students, teammates are essential for learning. People who have an intuition for which parts to use or what technology is temperamental may save time. This may be the difference between success and failure. However, this is not the same as being told explicitly what to do. From the student’s perspective, it is good for mentors to be honest about parameters and to be honest about their experiences with technology, if applicable. It is better to provide information to make as informed decisions as possible, but to ultimately let the student make the decision. Internship students reported that even failures are learning experiences. Sometimes a mentor or teacher may know exactly what must be done. Consulting with them, even if they do not share the exact step-by-step, is enough to get a student back on the right track. Teachers who are able to envision themselves as facilitators of the students’ learning process tend to be more at ease with the uncertainty and complexity inherent in challenge problem content, but adopting this approach in the classroom takes time (Flynn, Mesibov, Vermette, & Smith, 2014). Persisting in an autocratic approach to teaching in these technology-heavy settings may be overwhelming, and the lead time such a teacher would need to become comfortable with the technology and content to the point that they could support this approach would be significant. Simply staying up with the software updates and changes in capabilities would consume the teacher’s time. Training and support for teachers in order to transition to a constructivist approach to student learning, where goals include autonomy and empowerment (Fosnot, 2005), would make the task of teaching this content manageable.

Co-location of teachers with engineers and scientists provides an opportunity for teachers to directly observe the skill sets that are critical to the work conducted by these professionals. Opportunities should be given to allow for deliberate reflection on both the practices that stand out and the skills sets required for STEM professionals. Until they are able to get out of their classrooms and into real-world settings, teachers may lack opportunities to witness that one’s ability to understand and apply mathematical and scientific skills and content are separate from the problem-solving and coordination required to work in collaborative environments. Teachers who are able to facilitate interaction with mentors and between students and mentors will help to elevate the discourse for their students to observe and participate, which will impact students’ conceptual development (O’Donnel, Hmelo-Silver & Erkens, 2006).

Continued, active support for teachers is critical for success. Our team observed multiple cases in which a mentor can successfully support a teacher as they work to apply newly developed content and new technologies within their classroom. Given the complexity of some of the M&S tools that we have worked to integrate into the classroom, it has become apparent that teachers are dealing with technologies and experiences that are out of the norm for their classrooms and often out of their comfort zones. In addition to the support of a technical mentor to get them over hurdles, a teacher’s district leadership and administrators are critical contributors to the success of implementing new lessons, including M&S content. Coordination with mentors takes time, and often in-person interactions can be the most productive. The amount of flexibility afforded by the support of administrative and leadership staff within the districts can be a determining factor in the success of a particular lesson, course, or collaboration. For implementation of content across a number of districts, collaboration must be made a priority and flexibility for travel by mentors and teachers to the school or lab is a necessity.

Perhaps the most revealing of the observations made over the course of these efforts was that students, teachers, and mentors can be naïve and, at times, pessimistic about student capabilities. Whether it is an incoming intern responding to the complexity of the project, saying “good luck finding someone to pay to do this” or a teacher observing a day in the lab stating “my students cannot do this”, we have observed all parties, at times, express some doubt. Uncertainty and/or a lack of prior experience with these technologies may be the cause. Regardless of cause, we observed that students are capable of far greater feats than sometimes their teachers, mentors, and they themselves think. Incremental progress can be achieved in a period as short as a semester. Some of the students participating in the semester-long high school M&S course content were able to report that although they were not yet able to write software code, they could review the code and identify where problems were when they arose. Related to this observation, perhaps the most important transition that a team can assist a teacher in making is going from a place where they believe that “my students cannot do this” to one where they are asking “what resources will the students and I need to secure to support them through this project?”

STUDENT AND TEACHER OUTCOMES

The implementation of systematic, longitudinal outcome measures for this program is currently in progress, and will focus on capturing quantitative data regarding student engagement, motivation, and the impact of the M&S content on student learning and outcomes. Over the previous three years, anecdotal observations have been made regarding the individual experiences of students, both through internships and in the rural classroom, and the impact that the M&S content has had on them. We will divide our discussion by speaking about students taking the M&S content within their high schools, those interacting with content as Wright Scholar interns, and then we will conclude with a brief discussion on teacher impact.

By far, the most striking impact observed in the individual experiences of students are occurring in the high schools, where students are working with the M&S content as part of a course or as part of the Full Throttle STEM program. Overall, the M&S content is motivating students who previously had not planned to make it into the STEM career path. The Tri-Village LSD has never in its history graduated so many seniors with plans to attend college and major in STEM career fields. As previously discussed, this district imposed a prerequisite of algebra II in order for students to be eligible for the M&S course. As a result, they have seen substantial increases (140%) in the enrollment of students within upper level math courses. The district has also seen an 80 percent increase in graduating seniors choosing to major in STEM career fields and a recent eighth grade survey indicates an 86 percent increase in STEM career interest after taking the first in a series of courses featuring M&S content.

The success that these students are experiencing resulted in a number of secondary effects. The increase in mathematics enrollees required the district to work quickly in order to support the many students who are now taking the advanced mathematics. This district has won two national competitions in one school year, and their STEM lab now receives a steady stream of visitors. Students are becoming mentors to fellow students within their own district, with high school students assisting elementary students on projects. Teachers noted that the students’ newly acquired skills allow them pay forward the investment that has been made within their district, enabling them to support the growth of skills in others. Students often ask to arrive to the lab early and are frequently staying afterward to work projects even though there is no assignment due.

Comparison between the experience of students from Tri-Village LSD and those from the Wright Scholar program is difficult, given differences between the groups of students in terms of academic achievement. Many of the outcomes of the Wright Scholar participants interacting with the M&S content are slightly more subtle but also worthy of mention. In 2012, one of our Wright Scholar interns arrived at the lab with no prior programming experience. Having participated in the hands-on evaluation between MATLAB and the freeware alternatives, she realized that programming was an accessible skill. As a result she enrolled in a computer science class during her first semester following the internship, and is now in her third year at the university as a computer science major. Additional interns, following their first semester at their respective universities, have reached back to inform the mentors that their newly developed skills in 3D modeling transfer well to their undergraduate courses across a variety of majors including materials science and engineering. Students commonly report, at the end of their summer internship, that their research skills have vastly improved. Most strikingly, the student who had wished us luck in "finding someone to pay" to perform the hands-on evaluation of the game engines had left the lab at the end of summer with a completely different outlook, which is that she now had the research skills to find any information she was needing. Her outcome reflects the changes Flynn et. al. (2014) state is a result of the constructivist approach to learning, which is said to impact students' ability to identify useful and effective information.

The impact on the teachers themselves has the longest associated timeframe, as compared to that of the students. Tri-Village LSD was uniquely positioned to hit the ground running, as the teacher who spent the summer with our team developing the first M&S capstone project was also the one piloting the content and serving on the writing team to finish the curriculum. Since then, Tri-Village LSD has executed an additional two years of the content in their classrooms. Another teacher out of the Bradford Exempted Village Schools is beginning to emerge as a leader in the adaptation of her classroom to incorporate the open-ended challenge problem content focused on M&S and technology integration. Two years into her collaboration with both Tri-Village and the GRILL, this teacher is developing and modifying content for her classrooms. As the GRILL STEM program continues, we will focus specific efforts on tracking quantitative outcomes and the experiences that assist in shortening the timeline required to develop in teachers a baseline level of proficiency and comfort with the technology and adapt them for use in their classroom.

CONCLUSIONS

This program's history shows the feasibility of aligning commercial off-the-shelf M&S technology evaluations with STEM internship projects, affording hands-on experience for students while feeding products and findings back into the defense research setting and out to a larger community of students and teachers. Through these collaborations, it has become apparent that this type of sustained mentor/mentee pairing has helped to address a need that exists within communities such as the rural settings in the vicinity of WPAFB, where the capabilities of students exceed the rural communities' current capacity to support STEM and, more specifically, M&S skill development.

Game-based and 3D modeling technologies have the potential to increase the number of students getting into the STEM pipeline by helping to motivate them to complete the foundational work required in order to qualify for later opportunities. Additionally, programs that immerse students in challenge problem content in team environments have the potential to assist in retaining students in the STEM pipeline by providing students opportunities to develop collaboration and outreach skills that can be leveraged and further refined during their undergraduate programs of study. Substantial anecdotal evidence has been observed over the course of three years regarding these outcomes for students in both high school classrooms and USAF-led internships. Future work will include studies that measure the impact of this program and outcomes for both students and teachers.

Observations made over the course of the these internships indicate that the timeline during which students are impacted by M&S and game-based challenge problem content will depend on their prior history of success. Substantial gains may be made through short-term investment in students already achieving academic excellence. For these students, teachers have observed substantial increases in their problem-solving skills over the course of a nine-week internship, during which they transition from being very good at figuring out the answer a teacher is looking for to being able to evaluate various options for hardware and software in order to achieve a particular development goal. For those students who are at risk of excluding themselves from the STEM career path, the investment may require more time to ensure first that the motivational groundwork is completed and then time to maintain that motivation while students address any content deficiencies in the prerequisite courses they will need moving forward.

Establishing a baseline level of proficiency and comfort with M&S and game-based technology takes time and transformation by teachers to adopt a learner-centered approach to their classroom such as the environments reported on in this paper may take upward of three years (Flynn, Mesibov, Vermette & Smith, 2014). Through sustained teacher-mentor collaboration, the teachers will be better equipped to make this transformation and to guide students in this type of challenge problem-based content. Teachers have the opportunity to serve as a model for students as to how to reach out to mentors and to research and develop a system for problem solving that they understand will direct them to solutions. Teachers must be well-equipped to present real-world or authentic challenge problems that are deserving of student dedication. When students know that what they are doing is important and will be used by others, it makes them want to do their best and be the best. Students who have struggled to find their place in public education are usually the most striking examples of success. The administrative support that teachers receive substantially impacts their ability to persevere toward the goals of both creating and implementing engaging content that is grounded in real-world application. Continued support for teachers, both from technical and administrative perspective, and a realistic picture regarding the timeline required for progress are critical for successful implementation and refinement of M&S content in classrooms.

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