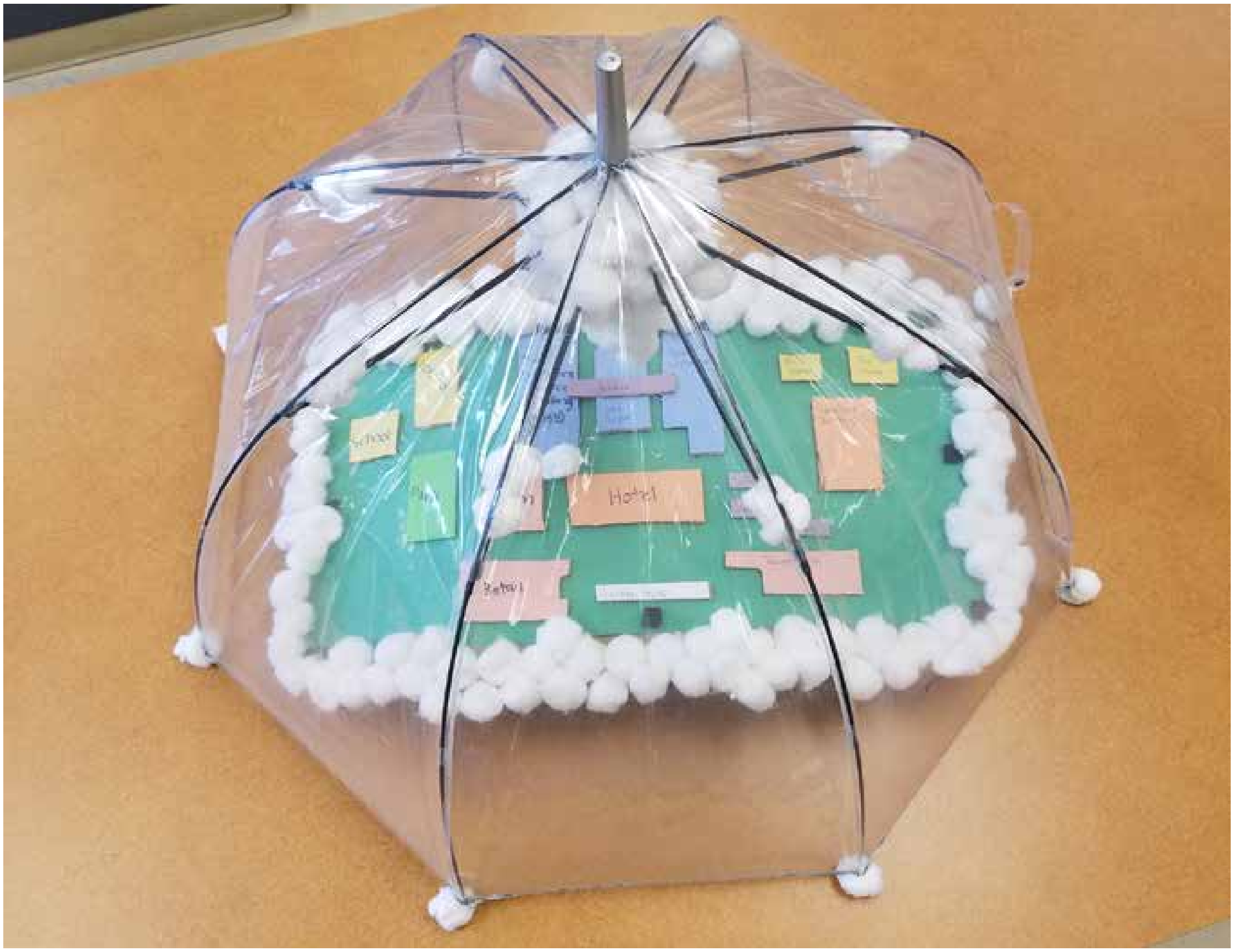
feature article



filling the gap:

integrating STEM into career and technical education middle school programs

There is no single strategy for approaching STEM integration.

Introduction

The field of STEM education is an educational framework that has surged in application over the past decade. Science, Technology, Engineering, and Math (STEM) is infused in nearly every facet of our society. Filling the gap of current research in middle school career and technical education (CTE) and STEM programs is important as traditional CTE programs transition to an environment that requires simultaneous academic and occupational instruction. The central strength of the current CTE and academic integration efforts has been "linking learned academic knowledge and skills directly with authentic applications in CTE programs and the courses of study opportunities" (Castellano, Stringfield, & Stone, 2003, p. 2).

Over the past decade, there has been an increase of research findings that "illustrate specific methods, actions, supports, and resources that facilitate the process of CTE and science content integration" (Spindler, 2011; see also Parr & Edwards, 2004; Stearn & Stearns, 2006; Washburn & Myers; 2010). There is no single strategy for approaching STEM inte-

by
Ray Wu-Rorrer

gration. No school or school system is the same. Each is unique in its own way, with differences in demographics, resources, socioeconomic factors, challenges being faced, or needs to be addressed. STEM integration, broken down into its simplest form, focuses on breaking down the silos of discipline-specific teaching by making the connections for students between the content being taught in the classroom and the real-world experiences they will be exposed to in the future.

The goal of this article is to provide additional research related to the *STEM Integration in Middle School Career and Technical Education* study (Wu-Rorrer, 2015) and to continue the expansion of the current base of knowledge related to STEM integration in career and technical education by providing an example of a project being incorporated into a middle school Inventions and Innovations course. The article focuses briefly on new research related to STEM integration and middle school programming while demonstrating how the current research can be implemented in a STEM classroom. The project being presented is titled the Future Space Colony Project (FSCP).

Review of Literature

Completed in 2015, the *STEM Integration in Middle School Career and Technical Education* study introduced readers to career and technical education, the Delphi design, and the Science, Technology, Engineering, and Math (STEM) concept. Research was originally conducted in five topic areas: (a) middle school education systems, (b) the Delphi design, (c) STEM, (d) career and technical education, and (e) career and technical student associations. The guiding question of the research study, *How can STEM programs be effectively integrated into middle school career and technical education programs?* was developed based upon the review of literature. Three additional subquestions were created to further explore strategies that would answer the guiding question. Three rounds of data collection were completed, and information was shared about the instrument, collection method, response rate, data analysis, and consensus parameters. Twelve strategies were identified upon completion of the qualitative Delphi method research study. The strategies of real-world applications and administrative buy-in were the two predominant strategies consistently addressed throughout the review of literature and all three subquestions in the research study.

The study sought to determine how STEM programs could be effectively integrated into middle school career and technical education programs by local, state, and national educators, administrators, directors, specialists, and curriculum writers (Wu-Rorrer, 2015). The study provided leaders in CTE with greater awareness, insight, and strategies about how CTE programs can more effectively integrate academics into career and technical education programs through STEM-related programming (Wu-Rorrer, 2015). The findings increased the limited amount of literature available for framing strategies for future STEM integration into middle school career and technical education programs. The project being presented in this article was based upon many of the strategies identified in the study.

Reason for Study

The original study was based upon an extensive review of literature from the past 20 years, and the study provided research in an area of CTE that has rarely been addressed in scholarly articles. Since the conclusion of the study, additional scholarly information has made its way into publication for review within the fields of career and technical education and middle schools. This article attempts to present some of this information within two of the five original areas of focus. Due to the very limited amount of scholarly research and information available about career and technical education, career and technical student associations, and the Delphi method since the completion of the study, they were not included in this article.

Recommendations and Relevance

The Wu-Rorrer (2015) study served as a foundation from which to continue to build the base of knowledge currently available about STEM Integration. Based upon the findings in the original study, the researcher recommended multiple topics for closer examination. This article is a continuation of the *STEM Integration in Middle School Career and Technical Education* study and presents new or previously unshared research related to STEM integration and middle school programs.

Theory: STEM Education

STEM education is the integration of the four disciplines; science, technology, engineering, and math, into one meta-discipline. The field of STEM education has become an extremely important educational framework that has surged in application over the past decade. Jacobs (1989) defined interdisciplinary curriculum as "a curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience" (p. 8). To motivate and inspire young people across the country to excel in STEM, President Obama launched Educate to Innovate, which to "succeed on developing clean sources of energy domestically, discovering cures for diseases, and addressing health issues such as obesity will require improving STEM literacy in schools while expanding a strong and innovative STEM workforce pipeline" (White House, 2009).

Although Castellano, Stringfield, and Stone (2003) observed, "focusing CTE on both career and academic-related measures is having the effect of encouraging new unions between CTE and academic departments in secondary schools" (p. 231), Lantz (2009) concluded that "most implementations of STEM education in K-12 schools have centered on the S and M of STEM, and not the S, T, E, and M" (p. 4). STEM integration into CTE programs has been sporadic, incomplete, and not properly practiced. Educational reform legislation (NCLB and the Carl D. Perkins and Technical Education Act) has required CTE educators to demonstrate that their students are realizing rigorous academic standards (Vail, 2007, p. 1).

Early Connections

Early engagement is crucial for the success of STEM integration initiatives. Rather than standardized test scores, a professed interest in STEM careers is the more accurate predictor of completing a science-related college degree for eighth graders (Tai, Liu, Maltese, & Fan, 2006, p. 1133). Several reports (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; UMass Donahue Institute, 2011) describe the effectiveness of national programs designed specifically to increase younger students' interest in STEM. Surveys of students showed a lack of STEM career awareness and connections to the real-world job opportunities available to them (Wiebe, et al. 2013). Students who plan early and strategically for STEM learning and who have access to high-level and rigorous coursework are more likely to be well prepared and successful in the STEM fields.

Importance to Future

As STEM curriculum and initiatives continue to move forward in mainstream education, each discipline will need to determine how to integrate and align STEM-related programming. The ability of educators within career and technical education to establish, maintain, nurture, evaluate, and expand upon current strategies and practices will be critical for the continued vitality of CTE. This article continues to add additional insight in the limited amount of information currently available related to STEM curriculum and its integration into CTE programs.

Theory: Middle School Education

Alexander (1969) argued that "junior high schools were solely designed to acclimate students to high schools rather than serving as genuine bridges between elementary and secondary schools, focusing on the unique needs of students of this age" (p. 38). The vacuous statements of Yecke (2006) claimed that "middle schools are an environment in which little is expected of students, either academically or behaviorally." Nothing could be further from the truth. Calling for a balanced curriculum based on student needs, *This We Believe* and *Turning Points* have been the "seminal position papers most often cited as authoritative descriptions of the middle school concept" (Heller, Calderon, & Medrich, 2003, p. 10). Davis (2000) argued that cornerstone middle school pedagogy includes a developmental focus more important than "an approach that stresses the academic needs of the child" (Hunt, Wiseman, & Bowden, 2003, p. 34).

Pedagogy

Research has concluded that "successful middle schools are effective because they often personalize the school environment to the students through context-based learning instead of the traditional lecture-based instruction" (Belfiore, Defoe, Folinsbee, Hunter, & Jackson, 2004; Greifner, 2006). Constructivism, problem-based learning, active learning, cooperative learning groups, and providing real-world connections are all techniques commonly used in effective STEM education programs (Smith, Douglas, & Cox, 2009).

Physically, middle school students need to move on a regular basis (Otieno & Wilder, 2011, p. 3). The active nature of inquiry and collaboration provides them with an appropriate venue to get up and move around the room. The benefits of collaborative learning have included "the development of interpersonal skills, active involvement in the teaching and learning process, enhancement of critical thinking, learning conflict resolution, and taking ownership of the project and results" (Otieno & Wilder, 2011, p. 1).

Career Awareness

Perry and Van Zandt (2006, p. 79) suggested "career awareness should lay the foundation for career exploration." Career awareness introduced in middle schools is a means for students to obtain a broad overview of designated strands in STEM and the major clusters of careers, such as Agriculture, Business, Family and Consumer Sciences, Marketing, Skilled Trades, and Technology. A student's education and learning activities are not just limited to the instruction given in the school classroom. Less than 20% of a student's waking hours are spent in school each year (Falk & Dierking, 2010).

It was reported that "students rely on peers, media, and parental influences to develop their perceptions of careers" (Perry and Van Zandt, 2006, p. 80). In Bardick, Bernes, Magnusson, and Witko's (2005) study, parents "believed that their child's career-planning skills increased with age but also thought that offering career exploration earlier in the child's education was important" (p. 156).

Application: Future Space Colony Overview

The first four classes of the course provide students with multiple content, theory, and career-awareness activities. Time is allocated for students to interact with one another, complete structured activities, and have discussions. During this time, the course instructor can observe and note the various personalities, interests, strengths, weaknesses, and abilities of the students. Students then choose their teams in collaboration with the instructor, with the goal of developing a well-rounded team that includes traits such as planning, designing, engineering, artistry, writing, creativity, video editing, video filming, and storyboarding. At the core of this project lie the theoretical constructs of systems thinking, experiential learning, and constructivism.

The Virginia Department of Education's *Inventions and Innovations* course description outlines that "students make models of significant inventions that have advanced society. After studying these developments, they explore contemporary technological problems facing them, their community, or the world and apply a systematic procedure to invent new products or innovations as solutions" (VDE, 2017). The course includes three competencies related to workplace readiness skills: personal qualities and people skills, professional knowledge and skills, and technology knowledge and skills. Six additional competencies covered are: (1) addressing elements of student life, (2) exploring inventions and Innovations, (3) exploring designing creativity, (4) applying the design process, (5) forming a production company, and (6) applying production management (VDE, 2017).

During the project orientation, students are provided a grading matrix for review. The first required component is a written plan of action that must be completed by the students and approved by the instructor prior to moving forward. The students are continually reminded that a failure to plan is a plan to fail. Once the plan has been approved, the teams are provided a basic framework for completing the informational and persuasive paper. The third component of the project is the presentation. The presentation is meant to serve as an infomercial, taking the details of the paper and adding a multimedia component to it in the form of video. The fourth, and most challenging component of the project, is the prototype. Consisting of four culminating parts, the prototype takes students from rough sketches to conceptual designs to blueprints prior to the completion of the physical prototype that is built from recycled material. Using a variety of techniques such as the history feature found in the various Google apps, peer reviews, and direct instructor observation, students are graded on their participation during the project.

Due to the multitude of standards, tasks, confidence, or approaches to learning that are required by the local, state, and national departments of education, it can be very overwhelming for newer or less experienced teachers to incorporate or embrace this form of experiential learning without fearing that they must stick to the prescribed curriculum. The Mary Ellen Henderson Middle School *Inventions and Innovations* course uses a slightly modified version of ITEEA's *Invention and Innovation* (4th Edition) as the theoretical foundation for the course, with the Future Space Colony Project serving as the application component. This modification was implemented during the 2014-2015 school year when the Encore rotational wheel (Career and Technical Education/Visual and Performing Arts) increased from four to five courses and became seven-and-a-half weeks in length rather than the original nine weeks.

Application: Plan

The first major component of the Future Space Colony Project is the plan. Regardless of whether one is using the engineering design model, the PIRPOSAL Model (Wells, 2016), or the International Baccalaureate design model, all include a planning stage near the beginning of any project. The plan allows students to develop their own projects and buy into the concept early in the process. "Open-ended projects allow students to develop and create all aspects of the Project, based on their existing knowledge, interests, and hobbies" (Nichols, 2017). Twenty-first century skills such as critical thinking, problem solving, collaboration, and communication are the primary goals that drive the plan.

A total of 16 days is allocated for students to complete the project. It is estimated that teams will develop the plan within three class periods. The plan must be completed and approved by the instructor prior to starting other components. At a minimum, the plan must include activities and goals for each of the 16 days of the project. It is recommended that the team members categorize daily activities into one of the four project components

(participation is excluded). In addition, students are given full control to make changes to the plan (highly recommended and encouraged) as the project develops. The plan component allows students to apply their classroom activities, team decisions, and planning experience to future real-life situations.

Application: Paper

The paper component of the project is an opportunity for the students to provide a brief synopsis of the concepts behind the Future Space Colony Project. The primary goal of the paper is to provide “prospective” colonists with clear understanding of what makes the colony so unique. By having students create an informational and persuasive paper, the teams are able to directly apply concepts being learned in their English courses while having a practical application outside the traditional English classroom setting. In a few cases, the teams have completed most of their papers within one class block. However, it is more common for students to complete the paper over two to three class blocks.

During the 2016-17 school year, efforts were made to ensure implementation of a variety of cross-disciplinary initiatives. Due to the cross-disciplinary nature of the Middle Years Program (the middle school International Baccalaureate program being used at Mary Ellen Henderson Middle School), unit planners are shared between the core academic subject areas and other subjects in the school system such as the Encore team. The MYP program, as with all International Baccalaureate programs, readily facilitates and encourages the cross-disciplinary approach that is so vital to the successful integration of STEM by helping to break down the silos of single subject-centered curriculum. In addition, the project often coincides with the discussions and civilizations, governance, and many other topics being covered in the social studies courses. Although the alignment is not always perfectly timed, students are able to access previous knowledge from what they have learned in their social studies courses or use the experiences learned through the future city project as a basis for future learning in their core classes.

To assist the teams with developing the paper, the instructor provides a general format that includes an introduction, three body paragraphs, and a conclusion. The paper is limited to 450 to 500 words. The introduction is required to provide background information about the colony by answering the 5 Ws: (1) Why is it important?, (2) What exactly is it?, (3) Who will be a part of the colony?, (4) When will it take place? (25, 50, 100, 250, or 500 years in the future), and (5) Where will it be located? These questions must be fully answered by the entire team prior to starting the presentation and prototype components. By design, the “how” is intentionally left out until later in the design process. The rationale for excluding the “how” is that it limits the students’ creativity as they will begin to spend their energies on figuring out how to build the colony using current technologies, not taking into consideration that the technologies 25 to 500 years in the future will be totally different. “What is not possible today will be tomorrow's achievements” is a phrase that is repeatedly stated during the development stage. It is at this point that some of the teams will begin to formulate what their invention and innovation will be.

It is suggested to the teams that the three body paragraphs include information on the colony’s governance, cultural norms, and information about the invention and innovation being incorporated into the space colony. Very limited information is provided to the students for this section, as each project is uniquely different and to avoid biasing the students’ decisions. Upon completion of the paper, students begin to fully buy into the project and are excited about moving forward. It is not uncommon during the paper-writing days for many of the students to say "thank you" as they're leaving the classroom or to state that this is going to be a fun project. Those two statements are the key indicators of student buy-in of the project.

Application: Presentation

The presentation is a three-part component of the Future Space Colony Project. The presentation culminates in a three- to five-minute video meant to serve as an infomercial for prospective colonists. It builds upon the details of the paper by adding multimedia. Having the students take written dialogue and create an audiovisual presentation adds a real-life perspective to the project.

The presentation is comprised of three equal parts: the storyboard, the script, and the video presentation. The storyboard is a basic written and visual outline of the video. Teams are required to break their video into at least six scenes, with each scene being at minimum 15 seconds but no more than one minute in length. Each scene must have a graphic that will communicate the theme and a minimum of three bulleted items. Upon successful completion and approval by the instructor, the teams can begin work on their scripts.

The script is a detailed, written outline that breaks down what each team member says and does. It includes notes on areas of emphasis and what background images will be used to set the context for those presenting. The script is organized using the storyboard as a guide and serves as an amazing opportunity for students to compose additional written works. Although script composition is not a part of the English classroom instruction, a few students have submitted sections of their scripts and been published in the school’s literary magazine.

Students are provided a lot of independence as they create the presentations. Many teams will create videos using the green screen and include images or videos that represent their future space colony. Over the past three years, this component of the project has served as an opportunity for the instructor to recruit students into the high school credit television and media production course by identifying students who enjoy capturing, editing, and publishing videos.

Application: Prototype

The prototype component is the most time-consuming and challenging part of the Future Space Colony Project. During this four-stage component, teams complete rough sketches, conceptual designs, and blueprints, all to complete the project's capstone, the prototype. Shortly after the paper is completed, teams are instructed to review their five Ws. Each team member is asked to complete an individual rough sketch, typically over a weekend, of what he or she believes the space colony should look like. Up to this point, no sketches are allowed to ensure that each student creates a unique design not biased by the designs of others. The instructions also require that students spend no more than five minutes on the rough sketches, which serve as the basis for completing the conceptual designs—so specific details are unnecessary at this point. Upon returning to the next class block, students take a picture of their sketches and place them in the prototype (Google) document for tracking the processes of how the prototype was built. They are then asked to share their sketches with their team. The team must include at least one element from each of the individual sketches and identify which member(s) will complete the conceptual design.

The conceptual design phase is typically completed by one or two students on the team and completed within three to five days. Rarely are conceptual designs approved the first time they are presented to the instructor. More commonly, three to five revisions are necessary before approval.

The blueprint has proven to be the most difficult part of the project for students to complete, primarily due to the designer(s)' ability to understand scale and proportion. As the middle school students develop physically and mentally, their ability to grasp orthographic drawing concepts is normally the limiting factor. To facilitate student retention and to bring the concepts to the real world, the instructor does a 45-minute field trip in and around the school. Students first complete a walkthrough with their team and guess the sizes of selected items. After all 15 items are given, the students measure each through the use of a rangefinder for the longer distances, an ultrasonic measurement tool for the classroom measurements, and a tape measure for the smaller items. As an extra incentive to keep students engaged, the team with the most correct answers will receive a prize. A 5% buffer is provided for their estimates.

Specific items that are used in and around the school include classroom size, a display case, doorways, a flagpole, the distance

from the softball field backstop to the scoreboard, the backstop to concession stand, the backstop to nearby parking garage structure, and the height of the school. It is extremely valuable for the students to be able to visualize their environment and make inferences when doing their designs. For example, a student might bring a blueprint for a 500′ by 500′ individual home for approval. By asking, "This house is the same length as the distance from the backstop to the concession stand... is that accurate?" Almost immediately, the students start working backwards and research average house sizes. Students normally decide on a house within the 1250 to 2000 square foot range.

To make the transition easier for students, they must complete hand-drawn blueprints on graph paper. Although many high school teachers will not approve, this modification is vital for middle school students. Many students are starting to use TinkerCAD or Fusion 360 to complete their blueprints. This can be attributed to the addition of the computer science course being added to the Encore rotation that exposes and trains the students on how to use the software. There was not enough time to teach the software in the *Inventions and Innovations* course. Upon completion of the blueprints, the students must determine if they will use a scale of 2:1 or 3:1 when creating their prototype. This is a precise process in which the instructor is very strict. The students have spent a lot of time getting everything correct and accurate up to this point. There should be no reason to allow them to be any less precise at this stage.

Using recycled materials is great. However, the items must have a purpose. As cited by Cool, Strimel, Croly, and Grubbs (2017) of Grubbs (2014), "authenticity may be lost when the learning of practical skills is sacrificed by using nothing more than hot glue

guns, index cards, tape" and "produce prototypes of solutions out of scrap materials" (Cool, Strimel, Croly, and Grubbs, 2017). The design should dictate the materials, not the materials dictating the design (this is important to remind students at this stage). However, just as in the real world and potentially in the future space colony, the materials may very well dictate the design. For this reason, if the students can argue their case for having the material dictate the design and make the modifications on their blueprints, the instructor will allow the change.

Two final requirements of the prototype remain. The first is the need for students to demonstrate how the basic necessities of life (food, air, water, and shelter) will be provided in order to sustain the colony for a minimum of 100 years. The second requirement is to ensure that both the invention and innovation are clearly visible and included in the prototype. This can be done by including it either as a part of the main prototype or as an enlarged/cutout version.

As the capstone of the project, a lot of time and energy is put into the completion of the prototype. Students commonly complete small sections or parts of the prototype at home or after school in the school's makerspace due to the limited classroom time. The prototype serves as a vehicle for students to research, plan, create, and evaluate a large, comprehensive project that provides a plethora of content knowledge while simultaneously providing the hands-on application the middle school students so desperately need.

Application: Participation

The final component of the project is student participation. This is an individual grade given by the instructor based on peer reviews, the instructor's direct observations, student documentation, and the review of files used by the students. The history feature within most Google apps can be a very valuable tool if used properly and accurately, but should not be the primary means for review, as there are ways the students can trick the system.

Daily student involvement in the project is vital to the team's success, "a student-centered environment facilitates student engagement and forces them to think at a higher cognitive level" (Nichols, 2016, p. 21). Typical student participation deductions are for unexcused absences, horseplay, getting off task, distracting others, playing video games on laptops during group work (1 to 1 school), being "checked out" mentally, not cooperating with the team, being a negative influence within the team, or having a negative attitude.

Although subjective, participation deliverables are quite simple. If the student shows up every day, gives an adequate of level participation, respects teammates, and does a fair share within the group, the participation grade is normally high. The participation grade is not intended to penalize students, but to distinguish between team members who work hard and those who do a very limited amount of work.

Conclusion

It is evident that STEM remains vaguely defined, and the strategies to successfully integrate it into the current educational system remain elusive. If the educational community continues to loosely use the term STEM without clarifying the term and embracing its many facets, the ability to develop effective strategies for implementing it will be greatly hindered. Kazis, et al. (2005) stated over a decade ago: "Career and technical education must continue to infuse more academic skills and knowledge into the curricula. Without such integration, policymakers will likely reduce resources for CTE and will shift those resources into other academic areas and programs" (p. 4). Ten years later, CTE has made headway in STEM integration, but there is still much work to be done.

By combining the theoretical constructs with a cross-disciplinary approach, the researcher believes this article will contribute to the limited amount of literature that serves to provide a framework strategy for future STEM integration within career and technical education middle school programs. The researcher also believes that the information provided in this article about the Future Space Colony Project serves as a successful example of STEM integration in middle school programs that make the real-world connections between the theories learned in all STEM courses and hands-on applications taking place within the Technology and Engineering classrooms at Mary Ellen Henderson Middle School.

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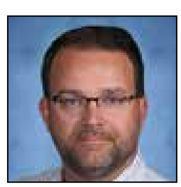

Ray Wu-Rorrer, Ed.D., *is a Technology, Engineering, and Robotics teacher at Mary Ellen Henderson Middle School and serves as the Collaborative Lead Teacher in the Career and Technical Education Department for the Falls Church City Public School System (VA). He can be reached at wurorrerr@fccps.org.*