Increasing Interest and Engagement in Elementary Science with Small Unmanned Aerial Systems

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Abstract: In recent years, much attention has been placed on the need for authentic learning opportunities that will effectively prepare our students to be successful in the 21st Century workforce. There has also been tremendous concern about the lack of scientists, engineers, and innovators in the United States. In response to these concerns, an extracurricular program focusing on providing elementary students with hands-on, integrated science, technology, engineering, and mathematics (STEM) education was established in 2012 at a public school in Hawaii and made available to students from across Oahu. The purpose of this project was to develop an instructional module focusing on the use of small unmanned aerial systems (sUAS) with the primary objective of increasing the level of interest and engagement in science among younger students. The ARCS-V Model was combined with project-based learning to have students explore and master STEM concepts required to construct a remotely-operated quadcopter by having students produce a different operational product each week to demonstrate their understanding of targeted standards and objectives. Activities and sub-projects integrated into and built upon in this module included rocketry, underwater robotics, electronics, model aircraft, radio communication systems. The results of this project have allowed instructional module to be improved upon by identifying areas in need of further scaffolding, providing a greater understanding of time and material needs, and offering insight into how the module can be implemented in different schools/programs, and with a greater range of students, both in Hawaii and beyond.

Introduction

STEM industries play a crucial role in ensuring the security and economic position of the United States (NGSS Lead States, 2013). However, the number of American students pursuing STEM-related degrees relatively low compared to that of many other developed nations, potentially making it more difficult for the nation to compete in the global marketplace and could consequently lead to a decline in the quality of life of many Americans (Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). These concerns have led to the creation of many secondary school STEM initiatives, but relatively few have been created at the elementary school level despite studies having shown a positive impact on students' perceptions and dispositions toward STEM-related careers (DeJarnette, 2012). In response to this, an extracurricular program focusing on providing elementary students with hands-on STEM learning opportunities was established in 2012 at a public school in Hawaii and made available to students from across Oahu.

A primary method of providing K-12 students with exposure to STEM learning has been through the use of educational robotics, which has the ability to address numerous concepts simultaneously, stimulate creativity, and engage students in complex problem-solving (Karahoca, Karahoca, & Uzunboylub, 2011). After acquiring the basic skill sets necessary to design, construct, and operate robotic platforms, students are then able to engage in more advanced projects that can further refine their problem-solving and complex thinking abilities, as well as provide opportunities to generate innovative solutions to real-world issues and engage in service learning activities.

Recently, an instructional module focusing on the use of small unmanned aerial systems (sUAS) was developed with the primary objective of increasing the level of interest and engagement in science among younger students in the elementary school grade levels. An action research study was then developed and conducted to evaluate the effectiveness of the instructional module in reaching its objective. The decision to use sUAS for a STEM-based instructional unit was based upon preliminary surveys of students' interests, the alignment between the process of building an sUAS with the Common Core State Standards and Next Generation Science Standards, and the ability to apply the knowledge and skills gained from a unit on creating a sUAS with authentic and service learning projects.

Literature Review

Throughout the United States and the around the world, greater emphasis on science, technology, engineering, and mathematics (STEM) has been called for by political, business, educational leaders (Atkinson & Mayo, 2010; Kearney, 2011). However, most STEM initiatives have focused only on secondary schools, despite studies showing that early (primary school) exposure to STEM learning opportunities increases the likelihood of students opting to pursue STEM-related studies and careers (DeJarnette, 2012). Moreover, STEM learning opportunities, whether they be at the primary or secondary level, are often infrequent and delivered through less effective traditional methods of instruction as opposed to more effective methods which are Constructivist in nature (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011; Bevan & Michalchik, 2013). Authentic, experiential, service, and integrative learning opportunities, examples of Constructivist models of education, have been shown to increase interest in STEM-related content and associated careers (Puviraja, Martin-Hansen, Verma, & Yager, 2012; Gilmore, 2013; Kearney, 2011) as well as provide instruction in a more effective manner (Becker & Park, 2011).

The United States Government, in addition to many other national governments, has repeatedly stressed the need for highly-skilled workers in STEM fields, and has drawn attention to the relationship between educational trends and the development of such a workforce (Atkinson & Mayo, 2010; Krug, 2012; USGAO, 2014). National "think tanks," such as the Information Technology and Innovation Foundation, have provided policy recommendations which stress a comprehensive approach toward the promotion of STEM education, including the development of effective institutions, incentives, information, interest, and industry (Atkinson & Mayo, 2010). Such recommendations have been met with both acceptance and criticism by those who recognize the importance of STEM education. Some, however, but feel that "the STEM movement has developed from a non-educational rationale" (Williams, 2011). In response to this criticism, there has been much more focus on research which has examined STEM education from a pedagogical and social-cognitive perspective, seeking to understand how learning can be made effective and efficient within the context of today's educational institutions, as well as how potential obstacles to STEM education and employment can be better addressed (Anderson, 2010; Raju & Clayson, 2010; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012).

The majority of research which has been conducted on STEM education has focused on which curricula and materials will best enable learning to occur, and less on large-scale reforms which will allow for more effective methods of instruction to be implemented (Henderson & Dancy, 2011; Stohlmann, Moore, and Roehrig, 2012). If the goal is to develop instructional methods which encourage more students to pursue STEM-related studies and careers, student interests, perceptions, and attitudes toward learning, as well as the content, must be taken into consideration (Christensen, Knezek, and Tyler-Wood, 2014; Honey, Pearson, & Schweingruber, 2014). Given the success of constructivist models of instruction, which provide tools that can assist in the implementation of this type of model, and how an instructor can best plan their utilization, also requires examination (Bloom, Burr-Alexander, Carpinelli, Hirsch, Kimmel, & Rockland, 2010; Ejiwale, 2012). Unfortunately, there is relatively little research on how tools can be best utilized within the context of effective instructional models (Benitti, 2012). Of the research which does exists, there are several indicators that robotics, utilized within the context of Constructivist styles of learning, can greatly increase student interest and motivation with short-term use, as well as significantly enhance the understanding of content with long-term use (Nugent, Barker, Grandgenett, and Adamchuk, 2010). Limited research has shown this to be true when similar instructional methods are utilized with students in different nations and cultures (Karahoca, Karahoca, & Uzunboylub, 2011; Tseng, Chang, Lou, & Chen, 2013).

Some studies have indicated that the design, implementation, and documentation of instructional practices that take into consideration effective pedagogy, learning styles, and educational standards are likely to be complex, difficult, and expensive. However, some researchers have also concluded that such efforts are likely to achieve the goals of STEM education and should be undertaken (Honey, Pearson, & Schweingruber, 2014). It has also been suggested that these efforts take into consideration both positive and negative influences on student perceptions, including those found in students' homes and communities. In addition, collaborative partnerships among schools, homes, community organizations, and industry are likely to yield positive outcomes for students (Wang & Degol, 2013; Watters & Diezmann, 2013).

Project Design & Development

The alpha level goal of this unit, as well as the program that it was developed for, was to inspire a new generation of problem-solvers and innovators with the ability and motivation to contribute to societies in meaningful and necessary ways. As challenging or farfetched as this may seem, this goal is also the expectation that many Americans have of educators. As societal expectations and needs have increased in recent years, so has the pressure on educators to produce greater results, in less time, with fewer resources. The aim of this particular action research study on an sUAS instructional unit to gain insight into how such goals and expectations may be better met.

The ARCS-V Model of Motivational Design, originally developed by John Keller, was used as a basic framework for the development of this instructional unit. This model was chosen primarily for two reasons: 1) more students are becoming uninterested, disengaged, and frustrated by science and math curricula currently being used in elementary schools, and 2) the aforementioned goals and expectations will remain unmet as long as long as these trends continue. Therefore, an instructional unit based on the creation of "drones," or small unmanned aerial systems (sUAS), was started with the intent of evaluating how such a unit could be aligned with national science and mathematics standards while increasing interest and engagement in science/STEM-related content. For the purposes of this unit, as for many STEM units designed for elementary STEM education, technology was generally regarded as the tools to work with science, whereas mathematics was regarded as the language of science, and engineering was regarded as the application of science to real-world challenges. Therefore, science was made the center of the instructional unit and the primary focus of the subsequent action research study. However, knowledge of science alone does not lead to students becoming highly-skilled problem-solvers or visionary innovators, making an integrated approach to science instruction necessary for the purposes of application, analysis, evaluation, and creation (often referred to as "higher order thinking skills").

A very important consideration in the development of any lesson, unit, or curriculum is the age-appropriateness of what is expected of students, as well as each student's present ability levels. Given the highly technical and complex nature of unmanned aerial systems, it was critical that such instruction be carefully scaffolded and continuously assessed while still maintaining high levels of student attention, relevance, confidence, satisfaction, and volition. In this unit, student confidence was of particular concern since the complex nature of the concepts and tasks have the potential to result in frustration and feelings of inadequacy, thereby requiring the careful selection of activities which will simultaneously lead to conceptual understanding, skill development, and feelings of success.

Methodology

This instructional unit sought to gain the attention of students by focusing on a high-interest topic and then providing opportunities to engage in tasks related to the topic through hands-on, project-based, inquiry-centered learning. How the skills and products explored and developed are relevant to 21st Century skills, the role they play in the local community, and how they impact the global community, were all continuously emphasized. The unit sought to provide challenging tasks requiring complex thinking, problem-solving, and collaborative decision-making in a minimally restrictive, experimental, and student-centered environment (also known as a “makerspace”).

The unit was designed to carefully scaffold content in a manner which would permit participants to experience success in each activity while gradually increasing the level of task complexity. Upon the successful completion of each activity, participants had a physical product that they were able to see function and operate as intended, thus providing a means of self-assessment. Beyond simply providing confirmation of success, and also served to both reinforce and increase positive beliefs about the participants’ abilities and skills.

Six workshops were held over the course of six weeks, with each workshop being held once a week for four to five hours. In addition, students had the option to work on the various projects introduced in the workshops on their own at home. Each workshop included one to two specific learning activities which were sequenced to provide scaffolded learning of progressively more complex concepts and skills. The first and second activities (rocketry and underwater vehicles, respectively) were combined into the first workshop, the third and fourth activities (model aircraft and communication systems) were done as a part of the third workshop, and the fifth and sixth activities (embedded systems and programming) were done during the fourth workshop. Having completed these activities, students were then ready to be constructing their sUAS during the fifth workshop, before testing and making revisions to them in the sixth and final workshop.

Before the first workshop, students and parents were sent (e-mailed) a copy of the pre-assessment to complete. In the event that a student did not have an e-mail address, a copy of the assessment was sent via their parent’s e-mail address or the student was simply provided with a link to access the pre-assessment. Although an option to take the pre-assessment at school before the first workshop was made available, all students were able to complete the pre-assessment prior to the day of the first workshop. However, only two parent pre-assessments were completed. The first round of interviews was conducted with students during the first part of the third workshop, and the second round of student interviews were conducted during the first part of the fifth workshop. All except one parent communicated that they could not make the time for an in-person interview, so two parent interviews (one for each round) were conducted in-person with the one parent who could come in, while all other parents were sent the interview questions via e-mail (one parent responded during both rounds of interviews). Post-assessments were completed online by all students following the completion of the sixth and final workshop, and the same two parents who completed the pre-assessments and interviews also completed post-assessments online.

The first activity on model rocketry introduced participants to planning skills, model construction, and operation techniques using materials originally intended for intermediate-level hobbyists using mathematical skills (measurement, computation, geometry) previously learned during the regular school day. Upon completion of the activity, participants had produced model rockets which could be launched and observed in flight, providing them with an introduction to basic principles of flight.

The second activity in the unit focused on underwater remotely-operated vehicles (ROVs) and required participants to learn and apply intermediate-level construction skills with a variety of tools, as well as integrate the engineering design process into the product's planning and development. The activity also required participants to learn and apply knowledge related to basic electrical components and systems (including the prototyping of circuits and soldering of components together using schematics).

In the third activity, participants constructed simple airframes using pre-cut foamboard components and installed integrated electrical propulsion systems to create remotely-piloted fixed-wing aircraft. This required participants to problem-solve both collaboratively and individually, as well as apply knowledge from previously-introduced activities alongside the engineering design process to plan and construct model airplanes that could be controlled with a radio transmitter and receiver.

During the fourth activity, participants explored communication systems and learned about the electromagnetic spectrum in order to better understand telecommand and telemetry instruments that could be used on their ROVs and RPAs. Participants were introduced to frequencies, transmission/reception technologies and designs, and how radio systems could be adapted for specialized tasks. Supplemental mini-lessons on newly-introduced components and their uses were provided, but how they could be installed and used to control structural components had to be determined by the participants themselves.

The fifth activity in the unit involved the use of embedded systems and required participants to develop a more in-depth understanding of electrical systems and their construction. Examples of this included making electrical calculations, troubleshooting systems, and gaining experience with specialized components that would be used later on in the sUAS projects. Students were also required to establish radio communication between a ground-based transmitter and a receiver mounted on their previously-created model aircraft, and then practice programming and calibrating their systems in preparation for doing the same on an sUAS.

In the sixth and final activity, participants were able to begin creating small unmanned aerial systems (sUAS) in the form of 250-size quadcopters (250 centimeters measured diagonally from motor to motor). This was the instructional module's culminating activity, and required students to draw upon previously learned concepts and skills, repurpose previously-developed components, utilize the engineering design process to design and construct flying robots that could be used in future "drone races." Each student had to program their own sUAS with specialized open source software, calibrate their system, and demonstrate proper function before being allowed to conduct test flights.

Analysis of Results

Throughout the implementation of the unit, student interests, motivational levels, attitudes, and perceptions were observed. Students were encouraged to provide feedback and communicate their feelings about the unit, and this information was used to determine changes, trends, and resulted in changes. Particular attention was placed on the five areas of the ARCS-V Model to identify areas of relative strength and weakness.

Conclusion

The instructional unit was found to be effective in engaging students in a STEM activity which they found to be of high interest, challenging, and engaging. The scaffolding which was used to structure the instructional unit in an age-appropriate manner in line with the students' abilities, which allowed all activities to be completed within the six-week implementation period. Feedback received from both students and parents was very positive, and both groups expressed strong interest in having similar learning opportunities in the future.

Several areas of need were identified through the action research conducted on this instructional unit, including the need for more time, additional instructors, and professional development. If the instructional unit is to be implemented with a larger population in the future, it is likely that instruction will need to be differentiated to accommodate a larger range of interests and abilities. It may be beneficial to obtain institutional review board approval for future projects so that results can be more widely shared.

Given the success of the instructional unit, is likely that similar units can be used to increase levels of student interest and engagement in science among groups of students similar to the target population of this study in the future. In addition, there are indicators which suggest that the instructional unit is likely to be effective in increasing levels of interest and engagement in technology, engineering, and mathematics among similar students. A study focusing on changes in achievement levels in these subject areas would be beneficial for determining appropriate implementation of the instructional unit in the future, and would likely provide useful information for decision-making purposes. It may also be beneficial to implement a similar instructional unit with a greater number of students in order to determine the likely outcomes of more widespread implementation.

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