AC 2011-1835: TECHNOLOGY EDUCATION E-LEARNING MODEL: THE SOUTH CAROLINA PARTNERSHIP

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Technology Education E-Learning Model: 
The South Carolina Partnership

Abstract

Recently, there has been a steadily growing movement for a more mobile and self-paced education such as that received in virtual E-Schools. To most, this is an attractive option as it allows the flexibility of holding a day job, traveling, supporting a family and advancing one’s education all in unison. However, few of these programs have focused on STEM education. Meeting this need, a synergistic partnership in South Carolina has emerged to create an National Science Foundation (NSF) Advanced Technological Education (ATE) regional center for aviation and automotive education aptly named CA²VES (Center for Aviation and Automotive Technology Education using Virtual E-Schools).

The CA²VES initiative is designed to meet workforce needs demanded by the more than 200 automotive-related and 160 aviation-related companies in South Carolina. As these companies drive the demand, the South Carolina Partnership agrees that they should also influence the Aviation and Automotive (A²) curriculum. Therefore, the new Technology Education E-Learning Model proposed will focus on the involvement of industry during the development and assessment of A² curriculum to generate a workforce that is prepared to meet the requirements of regional A² companies. Additionally, CA²VES will work to introduce new visualization and simulation tools (virtual reality, 3-D, etc) for next generation technologies to enhance personalized learning. Industrial collaborators, however, are merely one component of this strong partnership.

The CA²VES enterprise will bring together a South Carolina four-year institution, ten South Carolina two-year institutions, several South Carolina K-12 education partners, and three well recognized regional ATE center partners in the country. CA²VES will aim to disseminate curriculum and faculty development materials for two-year institutions, disseminate recruitment materials to high-school and career centers, and hold webinars to provide information about ongoing center activities. These efforts will culminate in creating a SC-A² network (and later a national network) for the advancement of aviation and automotive technology education. This paper will discuss South Carolina’s aviation and automotive industry workforce needs, the need for E-Learning and the role of CA²VES, the center’s goals and objectives, and the virtual reality (VR) module development component of CA²VES.

1. Introduction

A report conducted in 2009 showed a 17% growth rate for online enrollments from 2008 which far exceeds the 1.2% growth of overall higher education student population¹. The same report showed that 82% of those taking online courses are studying at the undergraduate level. As online classes and degree programs become more and more popular, students are able to find the appropriate program that allows them to hold a full-time job and still pursue additional education. However, few of these programs have focused on Aviation and Automotive education. Meeting this need, a synergistic partnership in South Carolina has emerged to create
an National Science Foundation (NSF) Advanced Technological Education (ATE) regional center for aircraft and automotive education aptly named CAVES (Center for Aviation and Automotive Technology Education using Virtual E-Schools). Industry and occupational projections compiled by the South Carolina Department of Commerce Labor Market Information Office for 2006 to 2016 indicate that job growth in South Carolina will increase at a slightly higher rate than in the U.S. The state is expected to add more than 200,000 jobs, representing a growth of 11% compared to 10% nationwide. Indeed, labor statistics seems to bear this out; South Carolina job growth for 2007 was at its highest rate in six years, up 2.3 percent to more than 1.95 million. Capital investment in South Carolina grew by 35 percent during the same year to more than $4 billion, representing more than 15,000 new jobs. Clearly the technical education community in South Carolina must meet this growing demand by ensuring that it produces a well trained and qualified technical workforce. Indeed, despite the economic downturn, South Carolina’s business environment has proven to be particularly robust. BMW in Spartanburg has announced expansion plans; Proterra, a new electric bus company has recently moved to Greenville; the ZF Group announced the construction of a transmission plant creating 1000+ jobs; and Boeing announced the biggest expansion in its recent times with plans to add 6000+ jobs at its new facility in North Charleston, representing the biggest capital investment in South Carolina.

1.1 Growth Industries in South Carolina: Automotive and Aviation

Two knowledge sectors in which much of this growth is reflected are the automotive and aviation industries. The transportation equipment manufacturing industry, for example, employed more than 40,000 South Carolinians in 2010. More than 51 firms involved in transportation equipment manufacturing relocated or expanded in South Carolina during the last three years, investing almost $2.7 billion and creating more than 4,500 new jobs. South Carolina’s knowledge economy is based upon the synergistic automotive [e.g. BMW, Michelin, Honda, BOSCH] and aviation [e.g., Lockheed Martin, Boeing, Honeywell, GE Energy/Aviation] industries, both of which have seen explosive growth since 2000 and require similar technical skills.

Most importantly, because the automotive/aviation technician skill set is portable, multiple career options for students are available. Employment opportunities for both automotive and aviation technicians are expected to grow most rapidly in the southeastern United States, and in S.C. specifically. As such, this strong CAVES collaboration with the other Advanced Technological Education (ATE) centers in Kentucky (National ATE Center, automotive), Alabama (Regional Center, automotive) and on the Space Coast of Florida (National Center, aerospace) will capitalize upon that growth. The state currently needs 2,000 to 5,000 automotive technicians; this number is expected to grow annually as the number of vehicles and their complexity increase. Projected growth for automotive technician occupations in SC is expected to be 8% for the period 2008-2012.

1.1.1 Automotive Industry

The current automotive industry in South Carolina is strong and thriving with more than 275 automotive-related companies located in the state, from Original Equipment Manufacturers
(OEM) to an expansive Tier One and Tier Two network of suppliers. This concentration of both OEM and suppliers has established the state as a driving force behind the Southeast’s growing automotive industry. This industry accounted for the largest share of capital investment and jobs in South Carolina in 2008, comprising 32.3 percent of all investment and 18.1 percent of jobs.

South Carolina is also an automotive manufacturing leader, with more than one in six employees working in 200 automotive-related companies. This industry accounted for the largest share of capital investment and jobs in the state, constituting 32.3 percent of all investment and 18.1 percent of jobs, with a $3 billion capital investment creating 11,000 automotive jobs since 2000. SC companies created 3,200 automotive industry jobs with a total of $4 million in capital investment in 2007, 2,400 automotive jobs in 2008, and $2.38 billion in 2009. Global demand for $13.9 billion in SC-produced manufactured goods generates nearly 118,000 jobs, and 1 in 3 jobs in transportation equipment manufacturing are supported by exports.

Today’s entry-level automotive technicians, who possess skills on par with a computer programmer, earn between $20,000 and $25,000 annually, which is comparable to four-year college graduate with a business degree. Experienced technicians average between $35,000 and $50,000 a year, with some specialists, such as transmission and drivability technicians, making substantially more. Figure 1 presents the projected employment and earning opportunities for automotive service technicians in South Carolina. This larger presence of manufacturing industries has dampened the effects of the current economic slowdown thanks to the importance of international trade in South Carolina. Projected growth for automotive technician occupations statewide is expected to be approximately 8% for the period 2008-2012.

![Graph showing automotive technician job growth](image)

**Figure 1. (a) Automotive Technician Job Growth and (b) Aviation Technician Job Growth**

Source: EMSI Complete Employment - Spring 2009 Release v. 2

### 1.1.2 Aviation Industry

There are approximately 160 aviation related companies within the state of South Carolina engaged in every conceivable aviation related task, from FAA-certified repair and inspection services to the construction of fuselage sections of the Boeing 787 Dreamliner. The establishment of the Boeing facility in the Charleston area and the existing Lockheed Martin facility in the upstate has now brought two of the country’s largest aerospace/aviation companies to South Carolina. Beginning in 2012, Boeing will employ over 6000 technicians and in steady
state will produce 10 aircraft per month each valued at 250 million dollars, for a net worth of $2.5 billion in finished products/month. This enterprise is a significant undertaking that will change the aerospace/aviation technician market for both South Carolina and the entire US eastern corridor. It is clear that to meet this need the state must accelerate the education of the technical workforce to meet the constant demand of qualified technicians within the next decade. Aerospace jobs, which are expected to increase significantly over the next few years, comprise 2.5% of all total jobs with an average wage of $41,621 annually. Projected growth for aviation technician occupations statewide is expected to be approximately 7% for the period 2008-2012 (Figure 1).

2. Regional E-Learning Needs and the Role of CA²VES

The need for this collaborative A² (aviation/automotive) Regional Center for E-Learning led by Clemson University, Florence-Darlington Technical College, Greenville Technical College and Trident Technical College is most apparent. Government, education and industry groups are beginning to address the deep and growing shortage of automotive and aerospace maintenance professionals.

While SC has 16 technical colleges serving 46 counties, the ability to prepare vast numbers of aviation and automotive maintenance professionals is seriously constrained through traditional face-to-face educational approaches. Whereas the need for these professionals in SC³-⁹, has become acute, current approaches have yielded only a fraction of the necessary workforce. The great challenge involves attracting, educating and upgrading “Next Gen” automotive/aviation technicians well-versed in both current and future technologies [e.g., automotive fuel cells/hybrid vehicles in automotive, composite/systems integration issues]. The current “brick and mortar” approach of using the resources of only a single institution to deliver this education is untenable; educators must work smarter and leverage the best available technology to prepare more and better graduates in a cost-effective way.

CA²VES, a center that draws upon statewide and other existing ATE center expertise to deliver effective technology education through E-learning, would bring a great opportunity for the state. CA²VES fills a state and national need for preparing aviation and automotive technicians while elucidating a greater understanding of the use of Virtual Classrooms as a pedagogical tool. CA²VES also meets two specific grand challenges for engineering and engineering technology as described by the National Academy of Engineering: i) the advancement of personalized learning, which moves from a generic type of educational style to one with more innovative, engaging, computer enhanced teaching techniques; and ii) the enhancement of virtual reality to create imaginative environments for education and entertainment. CA²VES brings together the academic strength of three of the state’s largest technical colleges with significant A² programs: the 3-D visualization development capability of the Southeastern Institute of Manufacturing and Technology (SiMT) at Florence-Darlington Technical College; and the technical, research, engineering, and leadership strength of both Clemson University (CU) and CU-ICAR (International Center for Automotive Research). The state’s leading A² industries (BMW, Michelin, Honda, Lockheed Martin, Boeing, GE Aviation) have participated in the planning process and enthusiastically pledge support to achieve the CA²VES vision. Created in 1995, the SC ATE National Center will serve as a mentor to
maximize the impact and effectiveness of CA^2VES, apply lessons learned in the ATE program regarding ATE Center management, and liaison with other ATE Centers to ensure national dissemination of research results and diffusion of innovation.

Because the automotive/aviation industries are vital to both SC and the southeastern economy, developing engaging computer-enhanced teaching techniques to meet diverse learning and scheduling needs for those pursuing A^2 careers is critical^5,10,13-17. Although E-learning opportunities have expanded greatly at SC colleges, options providing contextual learning in technology education are rare. E-learning in A^2 that provides content in the context of real-world applications, including hands-on laboratory experiences, has yet to be developed. Technology and software advances would make this possible if this resource is developed in a cost-effectively and collaboratively way and not college-by-college (as is done with E-learning in general education).

The primary target for CA^2VES E-learning is two-year technical and community college faculty and their students in associate degree, A^2 technician education programs. Working through partners within the South Carolina technical college system, CA^2VES will also use the virtual teaching environment to encourage and assist high school students in choosing careers as either aviation or automotive professionals. The CA^2VES initiative is innovative in that it specifically targets the young and more technology-oriented, which is the ideal point for building the foundation for a rewarding career. For example, the FAA-approved aviation training school at Greenville Technical College with 147 students can be made available statewide by expanding this comprehensive curriculum into virtual technologies and E-learning via the CA^2VES initiative.

Over the past decade, instructional technologists have developed numerous technology-based devices with improved efficiency and effectiveness, ushering in a revolution in education and workforce preparedness^18-24. Their use in technical education has yet to be fully realized, however^25. Research shows that education complemented with simulation and 3-D visualization, helps students learn faster and retain knowledge longer^26-38. Regarding technical education, the use of E-learning and visualization/simulation/VR (virtual reality) tools is restricted to nontechnical courses. However, the automotive and aviation industries have successfully pioneered the use of in-house and company specific proprietary programs^39-42. Although technical and community colleges have persistently adhered to traditional educational delivery modes, they are ready to embrace quality E-learning. The National Academy of Engineering (NAE) considers dissemination of E-learning tools to technical/community colleges to support technical of STEM education to be of the highest priority^24.

Government, education and industry groups are beginning to address the deep shortage of automotive and aviation maintenance professionals^7, 10, 11, 13, 43, 44. Budget and other constraints have stretched the SC Technical College System to capacity and hindered the ability of these colleges to prepare ever-increasing numbers of aviation/automotive maintenance professionals. While the need for these professionals in SC has become most acute, current approaches produce only a fraction of the necessary personnel. Consequently, the rationale for this proposal is clear. There must be a reinvention of methods by which these students are recruited and prepared for this industry by the state’s technical and community college system. The CA^2VES model will
close this gap by enabling the use of proven technology which can be deployed to reach state population groups who lack easy geographical access to the necessary education. Research results, applicable to K-12 education, technical colleges, online degree programs and corporate universities, focus on designing curricula to attract under-represented groups by using the personalized need based education paradigm.

Broader impacts include expanding the pipeline of youth entering the aerospace and automotive industry by developing alternative education strategies like the CA^2VES initiative, and enhancing the capacity of educational institutions to prepare students who demonstrate industry-defined competencies. Additional impacts include the development of industry-standard automotive technician training programs at technical colleges. These are all initiatives from the multimillion 2004 endeavor sponsored by the US Department of Labor to train new generations of aerospace and automotive technicians. In addition to obtaining a greater understanding of the use of the virtual school model as a pedagogical tool, CA^2VES will fulfill a regional need by providing a larger and well-trained talent pool of aircraft and automotive industry technicians. The map below (Figure 2) shows the proposed CA^2VES satellite locations and the distribution of the automotive and aviation companies in South Carolina alongside the academic institution partners.

![Figure 2. CA^2VES Satellite Locations and Distribution of Academic Institutions, Automotive and Aviation Companies in South Carolina](image)

3. Creating a Statewide Partnership

The CA^2VES team hosted three in-state workshops with educators and employers and three exploratory out-of-state summit meetings with the leadership of existing ATE centers. These meetings were attended by 152 participants: 77 from industry and government groups, and 75 from academia including K-12 schools who actively participated in developing novel methods for meeting the needs of the A^2 community. These collaborations were held at geographically dispersed A^2 locations across South Carolina: 1) CU-ICAR in Greenville, SC; 2) the S.E. Institute for Manufacturing and Technology in Florence, SC; 3) Trident Technical College in...
Charleston, SC. Outside state meetings were held at 3 NSF ATE center partners. An extensive SWOT analysis was conducted with participants during the in-state workshops. Results from these workshops and in-depth discussions with the leadership teams of existing A²-focused ATE Centers informed this project plan. From these conversations, it is clear that i) E-learning solutions must begin with educationally powerful modules (not full courses or curricula) that address core competencies in these two overlapping disciplines; ii) new content must be added to programs as emerging technologies become mainstream (e.g., alternate fuel systems, composites), for teaching non-destructive testing and trouble-shooting where equipment is expensive, unmanageable in terms of size, and where students need far more exposure to alternate workplace scenarios (parameterization) to become skilled at trouble-shooting and problem solving. Instructors and industry scientists/engineers will serve as subject matter experts (SME). All sites will facilitate field-testing and module evaluation, and the advanced technology applications will be designed/executed for E-learning delivery using the technical and VR expertise of Clemson University’s faculty in Industrial Engineering and Computer Science and the EON Reality Center at SiMT at Florence-Darlington Technical College.

4. CA²VES Center Goals and Objectives

CA²VES will increase the quantity, quality and diversity of highly skilled technicians in these critical disciplines. Learning modules will be developed or adapted as “plug and play” to maximize instructor and program flexibility in introducing/using E-learning. Modules may be coupled to create courses, and content may be used in many existing courses. The following are the primary goals of CA²VES:

**Goal 1:** SC A² Virtual School - Expand automotive/aviation technician education programs capacity at technical colleges via innovative, readily available, and cost-effective E-learning options

**Goal 2:** Increase access, support recruitment, and learning for students in automotive and aviation technician education programs by creating SC-A² Network.

**Goal 3:** Broadly disseminate advanced technology E-learning modules for use by automotive and aviation technician education programs and industry.

**Goal 4:** Advance CA²VES towards long-term sustainability.

5. CA²VES: E-Learning VR Module Development

CA²VES will support the development of high-impact, hands-on virtual reality 3D simulation and visualization modules for the A² industry. A large set of deliverables for the proposed work involves the creation of CA²VES experiences for students in A² programs and the associated pedagogical materials. Parameterization issues [too many variables to manipulate] often make it impossible to replicate real-world experiences. However, the proposed VR system affords us this flexibility to manipulate the various variables by immersing them in real-world scenarios for translation into improved educational experiences. Also by developing several scenarios in which students must use tools and develop skills [both basic and critical thinking], learning time will be reduced. The use of VR technology and 3D tools will enable educators to create and students to experience such complex automotive/aviation environments in the classroom. The Commission on Technology and Adult Learning noted need for such 3D educational tools that appropriately support learning conditions. The literature also shows that a highly interactive
learner-centric training and education experiences can potentially result in significant differences in student learning, retention, reinforcement and knowledge transfer. Effective and timely feedback, the ability to learn in a familiar work environment, and the opportunity to practice increases student success, thusly resulting in a faster transfer and longer retention of newly acquired skills. Through the completion of the center activities, CA²VES will directly impact 1000+ technical college students/yr (~30% women and minorities), 75 instructors in technical college programs, 2000+ high school students, 100+ K-12 teachers, 5-10 university students and 5 university faculty, 20 anchor A² companies and almost 4 times as many Tier 1 & Tier 2 companies in the initial years. The impact will be multifold (>3 times as much) when the model is implemented state wide and across ATE partner facilities.

For the curriculum VR module, the team will focus its initial efforts on creating modules in sets for the following courses common to both curriculums (see chart below). Examples include electricity, instrumentation systems, hydraulic and pneumatic systems, fuel systems, ignition and starting systems, inspection systems and NDI, aviation and automotive maintenance systems/diagnostics, engine overhaul and maintenance environmental systems- heating, induction, cooling and exhaust. Later module development will focus on advanced and next generation topics, including hybrid power systems and next generation fuel systems, composites, and green technologies. The team will work with NSF ATE Center partners to refine this list. The VR module development process is illustrated in Figure 3. This shows the involvement of each member of the partnership in the different stages of development, from needs analysis from subject matter experts (SME) to testing, assessment and dissemination to K-12 partners.

![Figure 3. Module Development Process Mapped with Activities](image-url)

To establish the educational requirements for each VR module, needs analysis will be conducted through relevant literature reviews and task analysis, interviews with industrial partners and subject matter experts [technical college instructors and out of state NSF ATE...
Through this process, the team expects to enhance the selection of representative scenarios and systems components to focus the graphic modeling efforts. It will explore different real-world A^2 industry scenarios, test instruments/systems and study their operations and functionality. Based on this effort, the development of specifications for generic VR modules will ensure that the simulations are flexible and adaptable to broad class of industry scenarios. Specifications for these modules will also include the different controls students may use during the task as well as performance data collection and feedback routines.

**Software development** will be informed by the Educational Requirements and Development Specifications. Here, the team will develop the VR simulation modules for incorporation in A^2 curricula. The ordering of appropriate software and hardware, and the installation and pilot test of the completed model will be done at ICAR/Greenville Tech, Florence Darlington and Trident Tech [demonstration sites]. Sufficient funds have been allocated to support laboratory creation at each of these facilities. The VR modules will be downloadable modules developed using EON, commercial off the shelf software, C++ and open GL graphic library for operation on a standard PC equipped with a high end graphics card. Using PC-based VR technology, the accurate representation of complex A^2 scenarios (see Figure 4) will enable students to experience actual conditions in which aircraft are built and maintained. Clemson University, in close collaboration with Florence Darlington Technical College, has developed extensive expertise through previous NSF, FAA and private industry grants to deliver these VR modules (see description of VRET Laboratory and SiMT Lab in Section I – Facilities, Equipment and other Resources). Details of the previous VR simulators are in^23^ and an example of innovative applications of the simulator is in^59^. Figure 4 shows VR modules that replicate an aft cargo bin inspection and borescope inspection process, respectively.

![Actual Cargo Bay](image1.png) ![Virtual Cargo Bay](image2.png) ![Actual Turbine Blades](image3.png) ![Virtual Turbine Blades](image4.png)

![Actual Borescope Device](image5.png) ![Technician Performing Inspection with Actual Borescope](image6.png) ![Technician Performing Engine Inspection with VR Borescope using a game controller](image7.png) ![Technician Performing Engine Inspection with VR Borescope using a Haptic Device](image8.png)

**Figure 4. Virtual Reality Modules**

Pedagogical material development will occur concurrently with the software development. The requirements will be operationalized into student learning objectives and described as
consistent with Bloom’s Taxonomy for the cognitive and/or psychomotor domains, depending upon the task involved. Incorporation of course plans, exercises, quizzes, exams and laboratory manuals into the appropriate modules at the appropriate level into relevant courses will follow. Instructors can use this reference documentation to create various scenarios by manipulating various parameters reflective of those experienced by a technician in the A² environment. To be effective, student learning assessments must be integrated into an academic department’s measurement system. Consequently, it must not impose an unreasonable workload in addition to the basic instructional requirements. In most programs, student learning is assessed through a formal process involving written and performance appraisals for specific course objectives at the appropriate teaching level. As such, the team will adapt the integrated assessment program to the assessment needs in terms of student learning objectives. Instructors at collaborating institutions will conduct the initial evaluation of the pedagogical material to support the iterative curriculum integration cycle. Figure 5 illustrates the integration of the software development and pedagogical materials into the assessment of the delivered course modules.

![Diagram](image)

**Figure 5. Integrated Assessment Program**

**Evaluation of software and pedagogical materials incorporating instructor training** will be conducted in two stages, first to the SC Technical College partners and later to out of state NSF ATE center partners. Extensive testing, evaluation and revision of the materials with the several academic partner sites will facilitate input from students from diverse backgrounds and academic settings. The team will then create the final iteration for use by instructors at K-12 schools.
6. Summary and Conclusions

This innovative approach represents a much-needed first effort to extend tested E-learning technology integrating visualization and simulation tools to the A² technology curriculum in SC technical colleges. CA²VES will introduce and evaluate next-generation teaching/learning to replace existing multimedia approaches, which, while valuable, cannot accurately reproduce the complexity of today’s processes and systems. CA²VES will provide alternatives for place-bound and capacity-constrained A² programs and for instructors facing significant challenges in teaching “legacy” technologies while introducing new and emerging technologies. CA²VES also provides solutions for meeting the diverse learning and scheduling needs of today’s students. In addition to obtaining a better understanding of the use of visualization/simulation/VR as a pedagogical tool, the successful completion of this effort will fill a state and national need for well-prepared technicians entering the A² industry. Immersing students in this CA²VES E-learning environment will provide them with a more realistic and accurate perspective of the complex A² environment, that can be effectively internalized and transferred to the workplace. Research results will also greatly enhance a wide range of science, technology, engineering, and mathematics (STEM) vocations. The team’s vision for CA²VES includes a series of deliverables that will impact South Carolina and eventually the nation. These deliverables include (1) an innovative, high-impact personalized learning virtual school curriculum model for training technical college students and industry employees in aviation and automotive maintenance; (2) an increased pool of skilled labor ready for immediate transition into industry; (3) development of recruiting and mentoring materials to attract under-represented groups to A² technology; (4) development of the virtual school as a standard pedagogical tool; and (5) creation of a national collaborative venture among Universities, community colleges, industry and high schools.

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