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Web-Based STEM Curriculum for Rural High Schools

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1. Introduction

STEM related technology and pre-engineering programs in rural high schools have always struggled because of the small number of students in the community to draw from. Most rural schools require the instructors to teach five or more different subjects. The teaching load placed on these teachers makes it difficult for instructors to specialize and be certified in any one subject and instead requires them to be stretched thin across multiple areas providing minimal knowledge in each course. The cost of a technology lab, software, and trained (certified) instructor is cost prohibitive to most small rural school districts. These problems lead to many high school students missing the opportunity of a complete and fulfilling STEM learning experience.

SUU (Southern Utah University) has piloted and is now offering the STEM related Engineering and Technology course. The courses are offered as concurrent enrollment and offered through several forms of delivery methods (online, hybrid, and a supplement face-to-face).

The course applies innovative online curriculum that has already been prepared, concurrent college credit, professor remote classroom support, and remote training workshops via GoToMeeting. SUU's program now offers students in these small rural schools similar STEM related educational opportunities as students in larger metropolitan schools. The information in this paper will provide background to the research, a brief review of the development of the curriculum, share a snap shot of the data collected from the pilot courses, discuss the changes made, and also show future directions for the course of the program.

2. Overview of this Research

This paper is a continuation of my research in the area of web-based Engineering and Technology curriculum. The research started with the publication of the first book in 2001, the CATIA V5 Workbook by Schroff Development Corporation. The first web-based training site was the CATIA V5 Workbook Website in 2003. The lessons learned from these publications have been applied to the university engineering and technology curriculum at SUU (Southern Utah University). The first paper and presentation was at the Ethicomp2008 conference[i]. The paper addressed the "Feasibility of Web-Based Training for Engineering and Technology." Once again at the Ethicomp2010 conference[ii], the subject addressed was the research on "What is Quality Web-Based CAD Training". The next research paper presented was "YouTube: An effective CAD Training Resource" at the 2012 ASEE Conference. In the ASEE 2013 Conference the curriculum development team co-presented the TICE (Technology Intensive Concurrent Enrollment) on "Development of an Open-Source Concurrent Enrollment Course that Introduces Students to the Engineering Design and Documentation Process". From that initial presentation, the TICE course has been piloted, data collected, and revisions made. The TICE course is now implemented across the state of Utah and has been delivered to rural high schools using a variety of delivery methods. The following information provides a more detailed outline of each phase of the research we conducted.

2.1 Phase I

As mentioned above, some level of research has been conducted on the subject of web-based engineering and technology curriculum since 2001 which can be found in the publication of the CATIA V5 Workbook. The motivation was to provide more CATIA V5 solid modeling training to practitioners around the world without the cost of time and travel. This prompted the development of the CATIA V5 Workbook website, which at one time had up to 2,000 subscribers from around the world. Data was collected from the subscribers which were used to make improvements to the website and content. The research was presented at several of the COE (CATIA Operators Exchange) International Conferences.

2.2 Phase II

The lessons learned from phase I research were applied to the engineering and technology curriculum at SUU. SUU offered concurrent college credit to high schools within the region. A majority of the region consisted of small rural high schools. Engineering and technology programs in rural high schools are difficult to maintain and are in jeopardy of being shut down, particularly in Utah[1]. The State of Utah Education System realized this and provided an opportunity for a grant to aid in the development of STEM curriculum. The grant was called TICE (Technology Intensive Concurrent Enrollment). SUU took the lead on this grant opportunity by leading a state wide team to develop a web-based engineering and technology course. The lessons learned from the Phase I research were used along with incorporating the concepts learned from the QM (Quality Matters) training and incorporating the concepts for the theatrical framework Community of Inquiry (reference Updated Literature Review). The course was named, IETD (Introduction to Engineering and Technical Design) and was developed during the 2012-2013 academic year.

2.3 Phase III

The IETD course was then piloted by 13 different high schools across the state of Utah during the 2013-2014 academic year. The pilot consisted of the following delivery methods:

Delivery Method	School
High school instructor	10
High school instructor led with support by SUU Faculty (using GoToMeeting)	2
Online Independent	1

SUU offered the IEDT class as a face-to-face college course to freshman attending SUU. The data collected from these classes was used by USOE (Utah System of Education) to evaluate the course and was then applied to the Double Loop Learning Theory to improve the curriculum. The updated course was available across the state of Utah in the 2014 Fall Semester. Again, data was collected from these courses and used to improve it in the next phase.

2.4 Summary of the Research History

The TICE grant has provided the state of Utah the opportunity to reach the Governor Herbert Educational Plan, 'On Pace to 66% by 2020'[2]. The objectives of this research helps fulfill the first three steps of the PACE plan:

1. Reach young students.
2. Provide STEM related curriculum to small rural schools (providing access to all students).
3. Help students complete a degree by receiving concurrent high school and college credit.

On a much larger scale, the contribution of this research could not only help preserve the existing engineering and technology programs in the state of Utah, but provide the avenue to starting new programs, particularly in rural high schools. There are numerous rural schools throughout the nation that could benefit from these findings especially with the dwindling resources[1].

2.5 Updated Literature Review

In the first few phases of this research, the frameworks and standards were the primary research topic. The frameworks used in developing the curriculum for TICE were the "Ten Steps to Effective Web-Based Learning"[3]. The team used the a variation of QM (Quality Matters) and Khans E-Learning Framework to gauge the quality of the curriculum, both of which are nationally accepted and recognized standards[4].

This phase of the research has focused more on the student teacher interaction and feedback from the pilot course. According to Harriman[5], the key to effective curriculum is making sure that the needs of the student, the instruction, and the delivery mechanism are all congruent with one another. Before being able to meet the needs of the students, the instructor must know what those needs are. Because there are many various learning styles, the curriculum has implemented one of the more popular style surveys VARK (Visual, Aural, Reading & Writing, Kinesthetic). VARK is sometimes criticized for lacking empirical support but continues to remain popular in education[6].

The curriculum has also incorporated the Community of Enquiry Framework[7] by which presents the concept that students participating in community engagement can become empowered, active learners and produce inspired work instead of being passive learners.

Tawfeek and Khalil[8] explain that one of the disadvantages of online learning is the student has to be highly motivated and responsible; unmotivated students may not complete the modules. He also stated that students sometimes feel isolated and cannot work without constant guidance. A majority of the online students need to be extrinsically motivated. In face-to-face classes, the direct interaction with the instructor and consistent assignments is generally enough to motivate students to keep up on their workload. Everson[9] developed a community of learners to help provide them with opportunities to learn from each other, share their findings, and become involved with their fellow students. She also believes that

solid deadlines are critical to keep the student motivated. Deadlines give the course a sense of legitimacy.

It needs to be understood that online courses are not for every student. This understanding emphasizes why it is so critical to known and understand what the student is bringing to the class in the form of foundational information, learning skills, and learning style. Stephens[22] stated "To succeed in autonomous online learning environments, it helps to be a highly motivated, self-regulated learner".

Massey's[10] research for Cengage Learning showed that students using online and digital content improved their academic performance by 52%. The same research showed that the students were also significantly more engaged because of the content included in the course. These are substantial indicators of improvement. If this is level of improvement could be seen by all students using online or digital content, the results would show substantial progress thus making the research significant.

These are main theoretical concepts that have been implemented into the IEDT curriculum based on the literature review.

3. Methodology

3.1 The Process

This information was obtained using action research which is a specific variation of Evaluation Research. McMillan and Schumacher[21] state" Evaluation Research focuses on a particular practice at a given site(s). The practice may be a program, a product, or a process" In this research, the product is web-based engineering and technology curriculum. Action Research is specific to education and learning using web-based technology and applying it to the engineering and technology curriculum. Even though Action Research is often mentioned as lacking a distinct theoretical base, it is a powerful tool in stimulating social change and exploring how to modify a situation or practice. Eileen Ferrance definition of Action Research is, "It is a reflective process that allows for inquiry and discussion as components of the "research." Often, action research is a collaborative activity among colleagues searching for solutions to everyday, real problems experienced in schools, or looking for ways to improve instruction and increase student achievement". The information learned from Phase I and Phase II of this research has been implemented.

Since triangulation can enhance the accuracy of the data[11], it has been applied to this research. The original concept of Triangulation was developed by Denzin[12]. He points out in his paper the term triangulation has also been called mixed methods, multi-methods and multi-strategy[12]. The original definition is not just the combining of qualitative and quantitative methods in studying the same research phenomenon, but is clarified by Hussein[13] as he states: "Triangulation is to be more precise as it aims to reveal complementarity, convergence and dissonance among the findings". Triangulation is known to strengthen action research and enhances the accuracy of the data by collecting data from at least three different sources. Murphy uses John Godfrey Saxe's parable of the Three Blind Men and the Elephant. The three blind men are using touch to describe the elephant resulting with each description being different, yet still correct. To get the totality of truth, all three viewpoints

must be considered. This is very similar to using triangulation in Action Research because it allows for the gathering of various view points from several different sources.

3.2 Continuous Improvement

In Phase I, the goal was to find the most efficient method of delivering CAD training to practitioners. In the beginning, the only method available was through the workbook, but eventually access to the online (web-based) training on the CATIA V5 Workbook Website allowed web-based learning to be an option. The Phase II goal was to apply lessons learned from Phase I as well as implement the frameworks and theories learned from the literature review to develop a quality web-based introductory engineering and technology curriculum for USOE (Utah State Office of Education) under the TICE Program. The goal of Phase III is to collect and apply the data from the pilot courses to improve the course and verify that it is not only a high quality curriculum but also an effective one from the perspective of the student, instructor, and stakeholders.

4.0 Collected Data

Data was collected using Surveymonkey tool for the courses taught in the 2013-2014 school year and the research found was used to update the following course. The same survey was used for the courses taught Fall of 2014, but this research is not included in this paper because of deadline issues. The teachers were interviewed using semi-structured survey questions as well as survey questions using Surveymonkey. Not all of the data is shared in this paper, only the items that emerged as significant results.

4.1 Student Data for 2014

Twenty two students took this survey which is a very small number for research. Filling classrooms and having multiple students is a constant battle for small rural.

From the following which did you find most helpful in learning the course material (1=least helpful, 5=most helpful)?

Table 2

Learning method	Average Usefulness (1-5)	How many students did not use	# of responses calculated in average
Online Presentation	3.588	5	17
Lecture(presentation)	3.318	0	22
Video	3.524	1	21
Module PDF/Power Point	3.409	0	22
Youtube	3.450	1 (out of 21 responses)	20
Working on team	4.000	4	18
Working on individual	3.238	0 (out of 21 responses)	21
Other	3.667	8 (out of 11 responses)	3

Comments: The conclusion that can be gathered from these results is that all students learn differently, and having a wide variety of resources for them to learn from is very beneficial to them as there are unique learning methods for everyone to try. The highest average usefulness was "Working on team" which is just high enough to stand out from the rest. The lowest was "working on individual," but at the same time, there were many students who really enjoyed "working on individual". These students were likely the 4 who did not use "working on team."

What is your Solidworks knowledge level (1=least knowledgeable, 5=most knowledgeable)?

Table 3

At what point in time:	Student average Solidworks knowledge
Before this class	0.818
After this class	2.773
Total Average Growth	1.955

Comments: Learning Solidworks was only one of several learning objectives. Table 3 would indicate that the curriculum used to present the Solidworks knowledge is increasing student knowledge.

The following table shows the growth from students starting from the same Solidworks knowledge level:

Table 4

"Before this class" Knowledge levels	Number of students at this level	Average knowledge level "After this class"	Average increase per knowledge level
0	14	2.643	2.643
1	5	2.2	1.2
2	2	3.5	1.5
3	1	3	0
4	0	-	-
5	5	5	0

The following table shows the students perception of whether they met the Course Objectives.

Table 5

Did the class Meet the Course Objectives?	Responses
Yes	86.36%
No	13.64%

Comment: From the student's perspective, the class is meeting the stated objectives. There are a few different methods that can be done to help clarify the course objectives as well as some adjustments to the assignments and assessments to help improve these statistics.

One of the open ended questions was: "What would you do to improve this class?" The responses were stated differently from student to student, but the overwhelming message was:

1. Simplify the numbering system for each module.
2. Simplify the navigation within Canvas (the LMS (Learning Management System)).
3. Consolidate the shorter assignments. Multiple assignments on the calendar can be confusing and overwhelming.

4.2 Instructors Data for 2014

Quality and efficiency are determined according to the perspective that is evaluating the subject. Both the student's perspective and the instructor's perspective are valuable to the progress of this research, but only the most significant items have been included in this paper.

When teaching a technology concept, tool, or process which of the following teaching tools do you use or have used (for the ones you have experienced (used) please indicate how effective you think the tools are.) (1=least effective; 5=most effective)

Table 6 Teachers Response Table

Teaching Tool	Number of Teachers who have no experience. Out of 13 total.	Average Effectiveness
Live demonstration	0	4.385
Video demonstration	0	3.538
Classroom discussion	0	3.615
Canvas (LMS) discussion	2	3.182
Reading about the subject (concept)	0	2.538
Reading (step by step)	0	2.846
PowerPoint Presentation	0	3.308
Videos (step by step)	0	3.615
Open ended questions	0	3.154
Project requiring application	0	4.154
Peer to Peer collaboration in the classroom	0	4.077
Peer to Peer collaboration online (Canvas/LMS)	3	3.200
Short exercises requiring application	0	4.000

Comments: One of the most significant items that emerged from the interview data was that the number of short assignments were too overwhelming for the instructor to manage. The other item of significance was the lack of a lesson plan.

4.3 Applying the Double Loop Learning to Update the Curriculum

There were numerous things that emerged from the data collection and analysis, but the items indicated above were the most relevant items found in the research. From this data, the major changes made for the Fall 2014 course were:

1. The modules numbering system was simplified.

2. The navigation of each module using canvas was simplified. Previously, there were multiple ways of accessing the materials and assignments. This confused students so the access was made more linear. We created an e-book with built in tabs on Canvas for the students to use. All of this information was taken out and replaced with an e-book in PDF format.

3. Assignments were consolidated so it did not appear to be as overwhelming. Each assignment was directly tied to a course objective; if it was not, it was removed.

4. Lesson plans were prepared for the instructors who wanted them (as suggestions).

5. The Final Assessment test bank was refined. The confusing questions were either restated or removed. If the question could not be tied directly back to the course objectives, it was removed.

5. Conclusion and Future Direction

The IEDT curriculum has been accepted and used in the state of Utah for two years now. The data shown in section 4 has been used to rebuild the curriculum from the criticism of students and teachers. It has led to fine tuning and improvement of the curriculum and its ability to ensure an effective means of teaching regardless of the method it is delivered to students in. The curriculum has been a huge success. Two tables which were not presented in section four showed the overall evaluation of the course by the students and instructors. Twelve out of the thirteen instructors perceived the course as being extremely beneficial to every engineering and technology program in the state. From the students surveyed, 94.55 % of the students would recommend the course to fellow students. All of the students agreed that the time spent on the curriculum was worth their time.

The USOE awarded the same curriculum development team another grant to develop a Residential Architecture course which is in the pilot stage this Spring Semester. The team will be applying the lessons learned to a new Engineering in the 21st Century course this semester.

The data collected this past Fall 2014 Semester will be analyzed to see if the same issues are addressed. As stated earlier, this is not meant to be a rigorous review of the curriculum, but more of a cursory overview to identify any of the most obvious issues. As those issues are resolved, a more in-depth and rigorous review will be conducted.

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