addressing manufacturing skills through online and hybrid curriculums in a rural region

by Raymond Dixon, Yudi Zhu, Jeffrey Ober, and Melinda Davis

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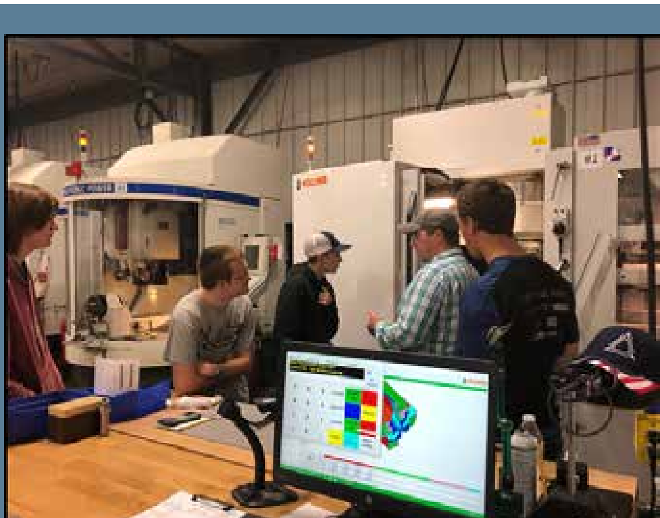

Figure 6. A tour of a manufacturing facility.

Introduction

The resurgence of manufacturing in the U.S. has seen North Central Idaho and nearby counties in Washington struggling to find enough talent for the growing manufacturing sector. Northwest Intermountain Metal Manufacturing (NIMM) supercluster, a group of companies that specialize in manufacturing of metal products, exists in this region. Clusters are generally formed based on an area's comparative advantages (Manning, 2013; Giuliani, 2005; Porter, 2003; Iammarino & McCann, 2006). This business cluster has a high concentration of metal fabricating firms and machine shops that are interconnected and specialized. They have similar workforce needs—workers who receive training in one firm can easily find work in another firm within the same cluster.

In 2007, through in-depth interviews conducted with 100 manufacturers, the lack of an available and trained workforce was identified as the most significant issue hampering growth (Frei, 2013). In a 2015 survey, again the NIMM Supercluster identified workforce as the largest impediment to growth. Presently, with the Metal Supercluster at accelerated growth, companies are competing for talent and leaving many positions unfilled. Increased competition for workers has resulted in increasing turnovers and higher entry-level wages (Tack, 2015). Higher retirement rates and a growing manufacturing sector combined with out-migration of young people have resulted in a serious shortage of talent for entry-level technician positions.

Challenges of Rural Schools to Produce Talent

The problem in this region, which encompasses rural counties in North Central Idaho and South Eastern Washington, is complicated further because most high schools are in remote areas, miles away from centers of manufacturing. In addition, some schools do not have a technology and engineering program, and those that previously possessed these programs discontinued them during the recent recession because of limited school resources. The region's strategy to address the out-migration of youth and the workforce shortage is to educate students about local job opportunities and equip interested youth with the appropriate technological skills to gain employment. Geographic challenges, limited school resources, and scarce population density significantly impact the educational system's ability to educate students and provide access to Career and Technical Education (CTE) programs. The region's twenty-two school districts struggle financially to find and employ CTE instructors. Co-locating CTE programs is nearly impossible because of distance. While individual manufacturers are eager to address the needs of their respective companies, manufacturers in the region recognized that collaborative efforts were necessary to systematically address the critical workforce issues.

Systematically Identifying the Developmental Needs of NIMM Supercluster

In 2011, a workforce development council was created as one of the outcomes of a previous Advance Technology Education project. This workforce development council, convened by the Clearwater Economic Development Association (CEDA), meets quarterly and is the forum for strategizing workforce development initiatives. The council consists of representatives from industry, K-12 school districts, two technical colleges, a university, state labor department, trade unions, and community organizations from North Central Idaho and Southeastern Washington.

In 2014, guided by discussions and decisions generated from the workforce development council, CEDA sought funding to develop an integrated strategy that would support and accelerate growth in the NIMM Supercluster (Frei, 2013). Funding was obtained through the U.S.D.A. Rural Business Opportunity Grant Program. The aim was to address the critical workforce shortage the region is experiencing in the Metal Supercluster by identifying the priority occupations for companies within the cluster, defining the skills needed to excel in those occupations, and then devising a strategy to develop training programs that will improve workforce availability for the business cluster. The CEDA workforce development council provided a venue for soliciting industry involvement in identifying the critical skills to be addressed in the program as well as in developing and offering the curriculum.

One of the greatest contributions of industry to the program was their involvement in the occupational analysis that was conducted with manufacturers from companies in the cluster to determine the jobs that are critical for the growth and the competitive advantage of companies in the NIMM supercluster. In addition, employers of regional manufacturing businesses allowed workers that they considered to be experts to participate in a series of job analyses using the DACUM (Developing A Curriculum) process. DACUM is a job-oriented groupware process that provides information about duties, tasks, general knowledge, supporting skills, attitude, and tools required to perform a particular job at a certain proficiency level (Morganson, Major, & Bauer, 2009; Finch, & Crunkilton, 1999; Norton, 1997, Brannick & Levine 2002; Clifford, 1994).

Based on these job analyses, funding was sought and secured from the National Science Foundation (NSF) Advanced Technology Education program (ATE) to develop and deliver a program to address the manufacturing workforce shortage in North Central Idaho and Southeastern Washington region. Industry partners formally committed support to the program through the Northwest Intermountain Manufacturers Association (NIMA). Two curriculums, Mechanical CADD and Electro-Mechanical, were identified as high priority to offer to high school students in order to provide them with the skills to gain entry-level employment in the manufacturing cluster. The program developed addresses several *STL* standards

Table 1. Relevant Standards

MSSC Work Standards	***STL* Technological Literacy Standards and Benchmarks**	
Manufacturing Processes and Production 1. Identify customer needs. 2. Determine resources available for the production process. 3. Set up and verify equipment for production process. 8. Perform, monitor and document the process to make the product. ***Quality Practices and Measurement*** 4. Inspect materials and product/process at all stages to ensure they meet specification. 5. Safety-related maintenance procedures. 7. Communication skills that enhance safety.	8. The attributes of design ▪ The design process ▪ Design problems are usually not clear ▪ Design needs to be refined 9. Engineering design ▪ Design principles ▪ Influence of personal characteristics ▪ Prototypes ▪ Factors in engineering design 10. The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving ▪ Research and development ▪ Researching technological problems	11. Apply the design process ▪ Identify a design problem ▪ Identify criteria and constraints ▪ Refine the design ▪ Evaluate the design ▪ Develop a product or system using quality control ▪ Reevaluate final solutions 12. Use and maintain technological products and systems ▪ Document and communicate processes and procedures ▪ Diagnose a malfunctioning system ▪ Safely use tools to diagnose, adjust, and repair ▪ Troubleshoot and maintain systems ▪ Use computers and calculators ▪ Operate and maintain systems

(*Standards for Technological Literacy*, ITEA/ITEEA, 2007) and the Manufacturing Skill Standards Council's (MSSC's) Work Standards for Production (2017).

Framework: Online Education

Because of the unique challenges of delivery of CTE in rural communities, online education is an appealing approach. The rapid growth of communication technologies and the high-speed internet in urban and rural communities along with the popularizing of personal computers have made access to online courses possible in many school districts, so face-to-face instruction is no longer the only option (Waits & Lewis, 2003; Picciano & Seaman, 2009; Watson, Murin, Vashaw, Gemin, & Rapp, 2013). For example, a survey revealed that 59 percent of responding high schools in the New York Greater Capital Region enrolled students in online courses in the 2012-13 academic year (Clements, Pazzaglia, & Zweig, 2015). A study conducted by REL Midwest in partnership with the Midwest Virtual Education Research Alliance showed that, out of the 117 Iowa high schools participating in 2012-13, only five reported that they did not use online learning. Additionally, in Wisconsin, only 10 of the 96 responding high schools stated they did not offer online courses (Clement, Stafford, Pazzaglia, & Jacobs, 2015). According to a study conducted by the Southwest Tennessee Rural Education Cooperative (SWTREC), more than 80 percent of responding schools in Southwest Tennessee used e-learning in 2012-13 (Holian, Alberg, Strahl, Burgette, & Cramer, 2014). More than six million students were taking at least one distance or online course (Allen & Seaman, 2017).

Importance of Hands-on Activities in Online Programs

Retention of students in online programs tends to increase with opportunities for face-to-face meetings and hands-on activities. A 2013 Chandler, Park, Levin, and Morris study that compared outcomes for 6,000 learners in a blended learning environment found that supplementing online learning with face-to-face, hands-on activities showed statistically significant improvement in learners' understanding of the course content. Building interactivity within the online program also increases the persistence of students in online learning, as found by Castaño-Muñoz, Duart, and Vinuesa (2014) in a study of 9,000 students.

According to York and Richardson (2012), effective interaction is not necessarily more interaction, but it is interaction resulting in learners thinking in new and more profound ways. Instructional interaction, therefore, must "challenge learners' thinking, shape the acquisition of knowledge in meaningful ways, and change learners, moving them toward achieving their goals" (p. 84). The most common interactive model in online learning is Moore's model, which stems from the field of communication and describes three types of interaction; learner-learner, learner-instructor, and learner-content (Moore, 1989). According to York and Richardson (2012), a recent meta-analysis supports the importance of these three types of interactions, and their strength is found to be associated with increasing achievement outcomes.

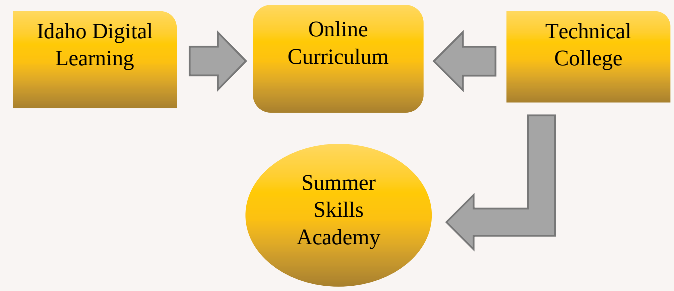

Figure 1. Mode of Delivery.

Delivery Modality of NIMM Curriculum

The two curriculums developed for high school students in the NIMM supercluster region were Mechanical CADD and Electro-Mechanical. The curriculum was to be offered over a three-year period. Realizing the advantages of online delivery of courses and the need for hands-on experience, a dual modality program was developed. A unique aspect of this program is the use of: Idaho Digital Learning Academy (IDLA); a state-sponsored school that provides online courses for high school students; and use of the four-year university and the regional technical college to develop and deliver nationally recognized courses in employability skills, CADD and blueprint reading, 3D modeling, and engineering design. In addition, facilities and resources at the technical college were leveraged to provide hands-on, project-based educational opportunities during the summer in machining and electronics (Figure 1). The coupling of these two systems of delivery to provide technical training is expected to provide a quality program while ensuring equity of access to technology and engineering education for these rural schools. To further augment the hands-on component, industry partners offered tours to students that provided a first-hand perspective of what these jobs entail. Additionally, industry partners have committed to having students for job shadowing and apprenticeship programs during their final summer of the program.

The program is comprised of two cohorts of students: 30 students in Cohort 1 and 60 students in Cohort 2. Cohort 1 students will complete the Mechanical CADD curriculum entirely online. Cohort 2 students will complete the Electro-Mechanical curriculum through hybrid courses. Both cohorts take common online courses during the fall and spring semesters from IDLA and the technical college, with the exception of Advance 3D Modeling and Introduction to Engineering Design (which is only taken by Cohort 1), and Mechaning and Electronics (which is taken only by Cohort 2 during the summer). Figure 2 displays the online courses. Both groups also participated in industry tours during the school year, and Cohort 2 students participated in additional industry tours during the summer. Students receive high school credits for courses taken through IDLA, and credits for courses taken through the technical college can be matriculated when students pursue an associate's degree in engineering technology at the technical college.

Examples of Summer Curriculum

The program was designed intentionally to engage students during the summer in order to motivate and prepare them for courses that are to be taken during the academic year. During the first summer, Cohort 1 students completed Applied STEM online, and Cohort 2 students attended the Summer Skills Academy. The latter were housed in dormitories at the technical college where they attended classes and laboratories.

Applied STEM

The goal of this course is to develop an understanding of analytical concepts from science and math domains in order for students to execute proper analysis (see Figure 3, example of problem-solving activity) particularly in engineering design, a course they will complete later in the program. As with all the other online courses, this course was designed to have a high level of interactivity with both the content and the instructor.

Topics covered include measurements, mechanics, and property of materials, linear and rotational motion, and fundamentals of electricity. Open source instructional videos (see example in Figure 4), simulations, problem solving, and low-stakes testing were built

The Online Curriculum

Online Courses		
Blueprint Reading	**Employability Skills**	**3D Modeling Introduction and Advance**
Students will be able to: - Describe line usage and visualizing compound shapes. - Identify and describe the purpose of various types of lines on prints. - List the six principal views of an object. - Understand the basic principles of orthographic projection. - Identify dimensions and designations of various Media Format sizes used in industry. - Interpret the information found in a typical Title Block. - Describe measurement systems, dimensions and tolerance. - Describe contours, angles and holes. - Describe section and auxiliary views. - Interpret geometric dimensioning and tolerancing. - Explain the use of assemble drawings in industry. - Read various assembly drawing. - Identify drawing components in a parts list.	*Students will be able to:* - Plan and organize work to manage time effectively and accomplish tasks. - Apply critical skills to solve problems, generate, evaluate, and implement solutions. - Demonstrate good decision making. - Develop fundamental knowledge of organization and industry. - Identify market demands and meet customer needs. - Select appropriate tools and technology to facilitate work activity. - Demonstrate personal traits such as initiative, dependability, reliability, adaptability, and professionalism. - Demonstrate the ability to work in teams - Demonstrate the ability to work effectively with those who have diverse backgrounds. - Perform effective communication.	*Students will be able to:* - Use parametric software to create boss and cut features, sketch relations, linear, circular, fill patterns, fillets, and chamfers. - Apply and edit smart dimensions. - Apply material and obtain mass properties. - Insert components into assembly and apply mates and constrain. - Communicate final drawings. - Create advance loft, sweep, rib, and shell features, and linear and circular patterns. - Create complex assembles. - Use advance mates, limit mates, and cam mates. - Create sheet metal models and forming tools. - Create weldments. - Perform top down assembly. - Perform engineering analysis . - Create designs using blocks. - Understand and repair errors. - Create photo views and simulations. - Produce detailed 2D drawings.
Applied STEM	**CADD**	**Introduction to Engineering Design**
Students will be able to: - Differentiate property of engineering material. - Use math to solve problems. - Solve simple mechanical, electrical/electronic systems. - Solve simple hydraulic and pneumatic systems. - Apply science principles to solve work related problems. - Solve linear and rotational problems.	*Students will be able to:* - Apply measuring and scaling techniques. - Create multiview drawings. - Create sectional views. - Arrange dimensions and annotations using appropriate standards. - Select appropriate existing title blocks. - Apply scaling factors, including plotting and printing. - Develop 3Dimensional models.	*Students will be able to:* - Define the problem. - Conduct background research. - Specify requirements. - Identify constraints. - Brainstorm solutions. - Perform analysis. - Optimize design solution. - Build a virtual prototype. - Communicate design solutions.

Figure 2. Online courses.

into the various modules. Feedback to students was provided in a timely manner by the instructor to avoid frustration on the part of the student and to motivate them, most of whom were taking an online course for the first time.

Summer Skills Academy

The Summer Skills Academy was a three-week-long (five days per week) residential program in machining and electronics held at the regional technical college. Students were engaged in hands-on, project-based activities relevant to the competencies for an entry-level electro-mechanical technician. A typical day included breakfast, lunch, and dinner; in-class instruction and lab with the instructor (Figure 5); two hours of study time during which students reviewed and practiced the curriculum supported by a coach; industry tours; and evening activities to bond and recharge with coach and chaperones. Due to laboratory space restrictions, Cohort 2 was divided into two groups at random; one group attended the machining course, and the other attended the electronics course. Groups will be rotated in the second year so that all students experience both sections of learning. Table 2 describes the content covered by each group.

Students engaged in project-based activities in the machine shop, CADD lab, and electronics lab. They applied concepts learnt previously in their online classes to basic procedures in the machine shop, CADD and electronic laboratories (Figure 5).

Industry Tours

As mentioned previously, several industry tours were arranged for students in both cohorts to visit various manufacturing facilities during the spring semester, and Cohort 2 had additional industry tours during the summer skills academy. Manufacturing facilities toured by students varied and included machine shops, foundry,

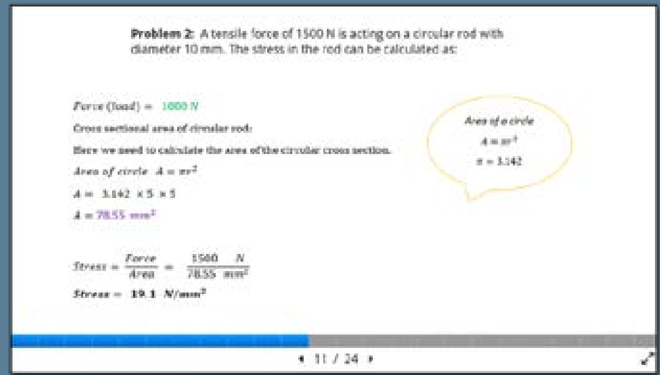

Figure 3. Sample of a problem-solving activity.

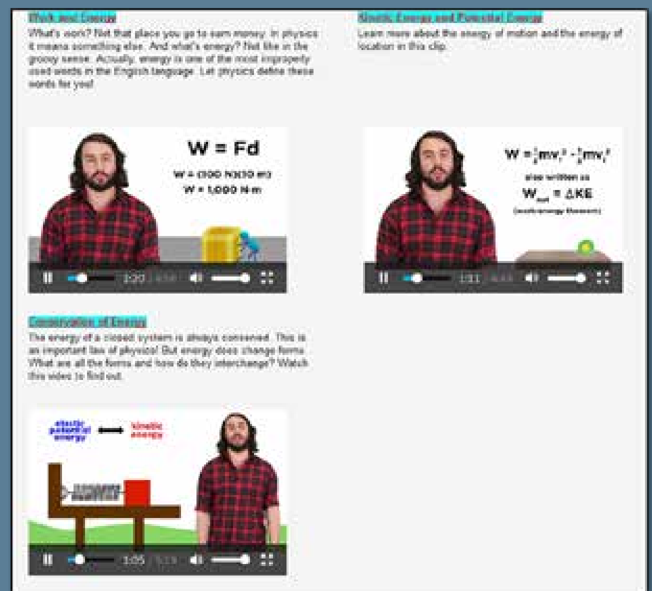

Figure 4. Sample of open-source instructional material.

Table 2. Machining and Electronics Content

Machining	Electronics
▪ Safety in the machining lab	▪ Introduction to D.C. circuits and electrical safety
▪ Quality control concepts	▪ Use basic test equipment
▪ Rigging and crane safety	▪ Construct basic electronic circuits
▪ Operation of manual equipment (bandsaw, lathe, mill, grinders, drill press)	▪ Draw basic electronic circuits (schematics) ▪ Introduction to relay control circuits
▪ Print reading and sketching	▪ Perform circuit calculations using Ohm's Law
▪ Write CNC machine code	▪ Use basic research techniques to locate replacement components
▪ Use calipers and micrometers	
▪ Perform benchwork activities	▪ Introduction to microcomputer hardware; disassembly and reassembly
▪ Basic Solidworks	
▪ Operate CNC lathe and mill	▪ Add a second hard drive, and hands-on experience with a microcontroller (Parallax)
	▪ Perform voltage measurements on computer power supplies
	▪ Introduction to solid state devices and circuits
	▪ Introduction to basic digital electronics with hands-on training with integrated logic devices
	▪ Introduction to programmable logic controllers with hands-on

Figure 5. Students in Electronics and Machine workshop.

boat manufacturing, hydraulic cylinder manufacturing, ammunition manufacturing, and gun telescope manufacturing (Figure 6, page 1). During tours, explanations were given about manufacturing processes, career opportunities, professional development opportunities, wages, and benefits.

Students' Perceived Benefits

Course and instructor surveys were administered to students following the online course and summer skills academy. Surveys consisted of Likert scale questions as well as open-ended questions allowing students freedom to comment. Students in Cohort 1 who completed the Applied STEM online class indicated that they were satisfied with the quality of feedback provided by the instructor and the level of interactivity embedded in the course content. As illustrated in Figure 7, most students either agreed or strongly agreed that the instructor demonstrated interest in them and provided timely and appropriate feedback to students' emails, as well as their questions and concerns. In addition, most students agreed or strongly agreed that the learned skills and content were valuable. Students' comments to the open-ended questions reflected their perception of the quality of interaction and feedback within the course. Examples of statements include:

"He provided insightful videos and helpful Powerpoints."

"I found all of the information I needed to be successful."

"He answered all my questions right away."

"He responded very quickly and answered all of my questions accurately. He also started the course a week early because he knew the students were busy, which I think was beyond helpful."

Students who participated in the Summer Skills Academy indicated in their evaluation that they received important hands-on activities in milling, lathe, CNC, programming, soldering, and electronics. For example, when asked, "What are the most important lessons or skills you will take away from this course?" some responses were as follows:

"Learning how to mill and lathe."

"Working the mill."

"Some basic machining capabilities."

"In the electrical sessions I will take away the basics of circuits and how they work and how to solder."

"The welding skills and soldering skills."

"I learned how to run new equipment and what college life is like."

"Coding and computer."

"I got more lathe experience."

"How to use the lathe and milling machine."

"Learning how to run machines to cut down stock."

"I have learned what motherboards are made of, and I learned how to service a computer."

"How to fix electronics and how to put them together (making them)."

Discussion and Conclusion

The components of the NIMM program addressed in this paper are demonstrative of the hybrid nature of the curriculum, which uses online platforms to reach schools in disperse rural areas while also providing hands-on, project-based activities at the regional technical college. Additionally, the regional economic development association and manufacturers' association provided informational and experiential activities through tours of manufacturing facilities. Combined, these activities provide a comprehensive curriculum that addresses workforce needs while meeting the challenge of offering technology education opportunities to schools in a rural context. At the time of the preparation of this manuscript, efforts were underway by the economic development association, department of labor, and manufacturers to implement job shadowing during the second summer and apprenticeship after students complete the NIMM program—experiential activities that will further strengthen the curriculum and learning.

The value of this program lies in the ability of a hybrid CTE model to deliver a manufacturing curriculum that meets the needs of rural communities with jobs in high-technology fields. The growth of business clusters can result in an increased demand on the existing regional knowledge base (Maskell, 2001). Failure of regions to provide a steady pipeline of skilled workers to meet the needs of the workforce can constrain growth and innovation in companies within the cluster and, by extension, the cluster itself. This in turn will affect the economic growth of the region because companies will relocate, if they are unable to find talent, to regions where skilled workers can easily be acquired (Cooke, 2002; Saperstein & Rouach, 2002; Kuah, 2002).

To ensure systemic production of this technical knowledge, Finegold and McCarthy (2010) argued that a viable option is for more partnership between governments, private sectors, education providers, etc., to foster the development of sustainable skills systems. In rural regions this can be challenging and necessitate innovative approaches, such as the use of online learning technologies and a strong collaboration between numerous stakeholders to ensure that high school students have equity in access to a curriculum that will provide pathways into existing jobs in manufacturing. Identifying the specific competencies required by the entry-level workforce in the manufacturing cluster, designing a curriculum that addresses these competencies, and working with stakeholders in the region to deliver the curriculum represents a pragmatic approach that is built upon advocacy of key stakeholders to address a regional talent pipeline problem. Such a strategy reflects elements of a sectoral approach to grapple with the shortage of skilled workers. Another unique aspect of this project is the approach to "regional" workforce development. Resources, quality of living, available personnel, and other factors that influence the establishment and growth of an industry sector like manufacturing do not start and end at state boundaries. The need to work across state lines to meet the growing workforce needs was recognized. When considering students in educational systems that are near to state borders, coordinating activities that include getting students involved in different states can be crucial. But it is also difficult to coordinate all the different school districts and governing authorities for those districts. However, the potential to impact both students' future and regional economic development can be large when working across state boundaries, but is worth the additional coordination.

After completing both curriculums and their high school education, students will have the opportunity to participate in apprenticeship programs with partnering manufacturers. The talent pool that will be available to companies through this educational pipeline will help to provide the foundation necessary to facilitate innovation, company growth, and high-quality jobs in the region. Not only does this approach to deliver CTE ensure equal access to a manufacturing curriculum by students in rural regions who seek livable wages after graduation, but it also provides a pathway for them to further their studies in advanced technological education at institutions of higher learning.

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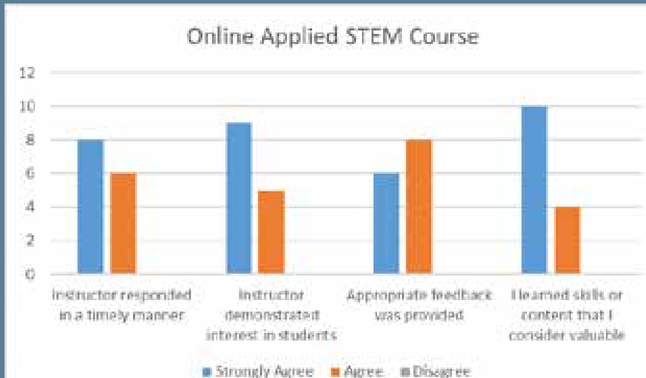

Figure 7. Applied STEM Course participant satisfaction.

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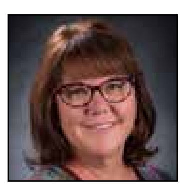

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