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Creating and Assessing an Upper Division Additive Manufacturing Course and Laboratory to Enhance Undergraduate Research and Innovation

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Abstract

This NSF IUSE project is on the Exploration and Design Tier and the Engaged Student Learning Track. It is aimed at better preparing the country's professional workforce in the renaissance of U.S. skilled manufacturing by creating new personnel proficient in additive manufacturing (AM). AM is mainstream; it has the potential to bring jobs back to the U.S. and add to the nation's global competitiveness. AM is the process of joining materials to make objects from 3D data in a layer upon layer fashion.

The objectives are to develop, assess, revise, and disseminate an upper division course and laboratory, "Additive Manufacturing," and to advance undergraduate and K-12 student research and creative inquiry activities as well as faculty expertise at three diverse participating universities: Texas Tech, California State Northridge, and Kansas State. This research/pedagogical team contains a mechanical engineering professor at each university to develop and teach the course, as well as a sociologist trained in K-12 outreach, course assessment, and human subjects research to accurately determine the effects on K-12 and undergraduate students.

The proposed course will cover extrusion-based, liquid-based, and powder-based AM processes. For each technology, fundamentals, applications, and advances will be discussed. Students will learn solutions to AM of polymers, metals, and ceramics. Two lab projects will be built to provide hands-on experiences on a variety of state-of-the-art 3D printers. To stimulate innovation, students will design, fabricate, and measure test parts, and will perform experiments to explore process limits and tackle real world problems. They will also engage K-12 students through video demonstrations and mentorship, thus developing presentation skills.

Through the project, different pedagogical techniques and assessment tools will be utilized to assess and improve engineering education at both the undergraduate and K-12 levels through varied techniques: i) undergraduate module lesson plans that are scalable to K-12 levels, ii) short informational video lessons created by undergraduates for K-12 students with accompanying in-person mentorship activities at local high schools and MakerSpaces, iii) pre- and post-test assessments of undergraduates' and K-12 participating students' AM knowledge, skills, and perceptions of self-efficacy, and iv) focus groups to learn about student concerns/learning challenges. We will also track students institutionally and into their early careers to learn about their use of AM technology professionally.

Background

Additive manufacturing (AM) is a growing trend in both industry and academia [1-4]. Any training in AM thus necessarily focuses on preparing the country's professional workforce for a possible renaissance of U.S. skilled manufacturing by creating new personnel proficient in it. This then creates an obvious goal for any college of engineering. AM is mainstream [1]; it has the potential to bring jobs back to the U.S. [2] and add to the nation's global competitiveness [3-

4]. Additive manufacturing is a class of manufacturing processes where material is deposited in a layer-by-layer fashion to fabricate a three-dimensional part directly from a computer-aided design model [5]. It was first demonstrated more than twenty-five years ago, but it has transformed significantly from its early days, when the primary market was rapid prototyping [6]. AM processes now can use metals, polymers, ceramics, and composites to manufacture a large range of durable and fully functional products in moderate to large quantities [6-8].

The global AM market reached sales of $3 billion in 2013 and is predicted to reach $10.8 billion worldwide by 2020 [9]. As one of the suggested areas of focus to support national manufacturing innovation announced by the White House, AM is now mainstream and triggering transformations of U.S. manufacturing [10]. According to a report released recently by PwC LLP in conjunction with the Manufacturing Institute, which includes findings from a survey of over 100 industrial manufacturers, two-thirds of manufacturers surveyed currently implement AM [11]. Among the numerous companies employing AM are GE, Lockheed Martin, Boeing, Rolls Royce, and Google [12, 13].

However, to our surprise, there were no permanent courses focused solely on AM either in our respective colleges of engineering or at various colleges of engineering that we surveyed around the country. Thus, the course described in this paper is supported via the National Science Foundation's IUSE's Exploration and Design Tier and Engaged Student Learning Track (grant number 1712311). The objectives are to develop, assess, revise, and disseminate an upper division course and laboratory, "Additive Manufacturing," and to advance undergraduate and K-12 student research and creative inquiry activities as well as faculty expertise at three diverse participating universities: California State University Northridge (CSUN), Texas Tech University (TTU), and Kansas State University (KSU). CSUN is a HSI (Hispanic Serving Institution), AANAPISI (Asian American Native American Pacific Islander Serving Institution), and non-PhD-granting institution. TTU is a university with high research activity (RU/H), while KSU is both an Established Program to Stimulate Competitive Research (EPSCoR) and RU/H institution.

Our research/pedagogical team contains a mechanical engineering professor at each university to develop and teach the course, as well as a sociologist trained in K-12 outreach, course assessment, and human subjects research to accurately determine the effects on K-12 and undergraduate students. The course is being run simultaneously at all three universities in three consecutive spring semesters: 2018-2020.

Course Need and Description

Our course is a pioneer of its kind. In 2016, we conducted a survey of more than 180 representative 4-year colleges and universities (including at least two institutions in every state) across the United States. This survey revealed that only a few institutions are teaching additive manufacturing, however, an upper division standalone course with hands-on labs on additive manufacturing (such as ours) is hard to find in undergraduate catalogues. Given the diversity both of students and of institutions in our course, we argue that the course materials (such as lab manuals, projects, etc.) that come from our course will facilitate widespread adoption of the course and its materials.

This course provides detailed principles, theories, and applications of additive manufacturing (AM) techniques, such as extrusion-based, powder-based, vat photopolymerization, material jetting, etc. For each AM category, definitions, principles, advantages, and limitations are demonstrated. The class will study the connections among materials, processes, and properties during AM fabrication of parts. Design for additive manufacturing, development of state-of-the-art AM, and future directions are covered. This course will also address the following consequential aspects of AM: (1) process mechanics; (2) machine design/assembly and mechanisms; and (3) novel interdisciplinary applications of AM.

As mentioned above, AM is a manufacturing process that joins materials layer by layer through a digital 3D model. Thus, the ability to draw a 3D model using software, such as SolidWorks, Creo, AutoCAD Inventor, etc., is a prerequisite for this course. After successfully completing the course, the students are expected to be able to (1) understand the core concepts and evolving technologies of different AM processes; (2) create the design of an object suitable for AM processes and use commercial software to digitize the free-form geometry; (3) describe and evaluate the capabilities, procedures, typical applications, the relative advantages and limitations of AM processes; (4) define and apply the criterion to select the appropriate AM process for any given applications; and (5) gain hands-on experiences on the AM of fabricating and testing parts as well as provide solutions to the current problems in AM.

Our specific learning objectives can be found in Figure 1. To effectively prepare students, we cover extrusion-based, liquid-based, and powder-based AM processes. For each technology, the fundamentals, industry applications, and current advances are discussed. Students learn solutions to AM with polymers, metals, and ceramics. Two lab projects have been designed to provide hands-on experiences on a variety of state-of-the-art 3D printers. To stimulate innovation, students design, fabricate, and measure test parts, and perform experiments to explore process limits and tackle real world problems. As both a pedagogical technique to deepen the undergraduates' understanding and to engage the surrounding community, enrolled students also mentor selected K-12 students through video demonstrations and team leadership in person or via Skype, thus developing presentation and leadership skills.

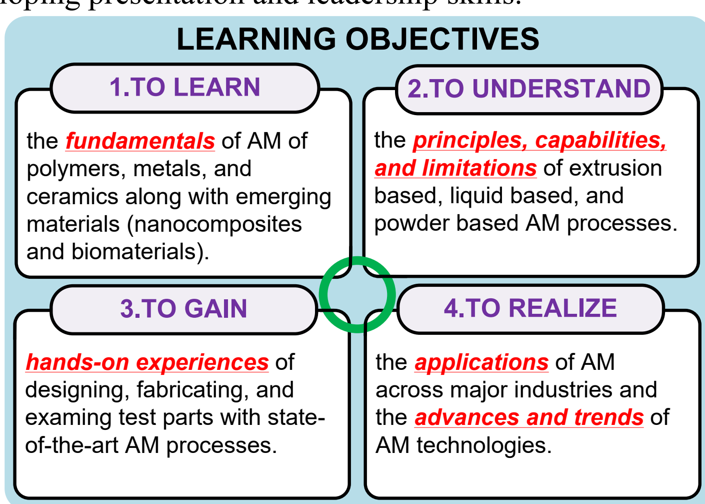

Figure 1. Learning objectives of the proposed course

The lecture section includes the following fundamental knowledges: historical development, fundamentals of AM, advantages and disadvantage AM, classification of AM systems, AM process chain, 3D modeling and support design, data conversation and transmission, post-processing, liquid-based AM (stereolithography, polyjet, multijet, aerosol jet, two-photon polymerization, rapid freeze prototyping), extrusion-based AM (fused deposition modeling, multi jet fusion), powder-based AM (selective deposition lamination, electron beam melting, selective laser sintering, selective laser melting), STL data format, STL file repair, medical and bioengineering applications, benchmarking, and the future of AM.

Apart from the lectures, a variety of laboratory projects are integrated and conducted at the newly formed teaching lab (Stinson lab) in the Department of Industrial, Manufacturing, and Systems Engineering. Specifically, the tasks will contain: (1) infill and structural designs using Fused Deposition Modeling (FDM) process and object evaluations; (2) the FDM 3D printer assembly to understand the machine mechanism; (3) a lattice structure design using vat photo polymerization AM process with ductility property testing; (4) a keychain design using powder-based laser additive manufacturing; and (5) fabrication of a part with great functionality and at least one motion mechanism using material jetting AM process. These practices in laboratory sessions will enable students to have a better understanding of how different 3D printing processes work, which will guide them to solve engineering problems using 3D printing technique in the future. The lab section includes the following hands-on activities: anatomy of AM machines, measurements, AM fabrication, AM testing, AM post-processing, AM material heat treatment, 3D scanning, and 3D bioprinting. Additionally, real life projects collaborated with local companies are ongoing: Northrop Grumman, Harley Davidson. AM industrial field trip and guest speaking are also included.

Besides instructed lab sessions, students are divided into teams and each team is expected to complete a semester-long, unique project. Key event timeline is presented to the students including: topic proposal, state-of-the-art literature review, AM system design, feasibility study, design of experiments, measurement procedures, experimental study and data collection, data analysis, report, and presentation. These team topics are proposed and chosen by the students spanning over AM for veterinary medicine, upper limb prosthetic printing, concrete printing, food printing, fiber reinforced printing, jewelry printing, etc. A 3D printer kit is provided to each team, and a team has to create or modify the material delivery mechanism to make the self-built 3D printing be able to print the team's customized materials. Students are given access to many cutting-edge metrology and characterization research facilities to perform a comprehensive assessment of the system they developed.

Research Focus

Much research that tracks the effects of a new course or an innovation in engineering education focuses either on changes in undergraduate knowledge [14] and/or attitudes towards the topic [15] within a single university. The former (i.e., change in knowledge) often uses some proxy like course grades or performance on a particular project or exam to ascertain student knowledge change. Utilizing course or project/exam grades may contain bias not only because there is sometimes no baseline metric upon which to determine prior/exogenous knowledge, but also because such grades are normally a) not anonymous to the instructor(s) and b) can be affected by the instructor's own grading biases.

Changes in attitude toward a given topic or engineering in general is valuable knowledge, given the effects of student perception on graduation rate [16] and eventual employment [17] as well as less easily measured variables like satisfaction in engineering and creativity in the discipline. There are multiple methods to measure changes in attitudes, varying from using ABET standards [18] to more inductive models based on student's retrospective written or oral evaluations of how the course has affected them [19]. As with any more antipositivist metric, these methods too can contain bias, in that humans generally ascribe worth to anything they have invested work or energy in (such as a course) or students may wish to please their instructors with positive assessments. Using a standards-based assessment alone may be inauthentic in that it could miss some of the ways students perceive that the course or innovation has affected them. Additionally, any attitudinal metric that is only completed retrospectively contains bias.

Therefore, to accurately assess both a) knowledge and b) attitude changes in the enrolled undergraduates and knowledge and attitude changes in the mentored high school students, we triangulated our assessment via multiple methods. Through the project, different pedagogical techniques and assessment tools both have been and continue to be utilized to assess and improve engineering education at both the undergraduate and secondary levels through varied techniques: i) undergraduate module lesson plans that are scalable to secondary levels, ii) short informational video lessons created by undergraduates for secondary students with accompanying in-person mentorship activities at local high schools and MakerSpaces, iii) pre- and post-test assessments of undergraduates' and secondary participating students' AM knowledge, skills, and perceptions of self-efficacy, and iv) focus groups to learn about student concerns/learning challenges. We have also tracked students institutionally and will track them into their early careers to learn about their use of AM technology professionally. The data presented in this paper are from the first year of the course. We look forward to adding to its complexity and validity via the second and third years in the future.

Data and Metrics

Knowledge Assessment - To determine change over time in undergraduate knowledge about additive manufacturing, we first designed a 15-question quiz containing 10 multiple choice and five essay questions that covered all the topics in the scope and sequence of the course (in our shared syllabi). Please see Appendix A for a transcription of this quiz. On the first day of class, our assessment expert either personally proctored this quiz or sent a trained sociology graduate student to do so. Students were assured that their quiz would remain anonymous to their engineering professor and told to "just do their best" on this assessment. At the end of the semester, on the last class day, this quiz was repeated, again personally by evaluator or her surrogate. The engineering professors never had custody of the metrics and did not know the identities of the students. No course grade was attached to their performance on the metric, per the ethics guidelines of TTU's Human Research Protection Program.

These collected quizzes from all three universities were then assigned a random three-digit number, put in order according to that number, scanned, and sent to the engineering professors to grade. Multiple choice questions were graded in advance (since there was only one right answer for each). Each engineering professor was responsible only for one to two essay questions throughout the entire stack, to maintain comparability across the assessment. A rubric with point breakdown was written in advance for each question to make sure that grading standards remained the same throughout the process.

A similar process was undertaken with the secondary students, albeit on a smaller scale. The quiz questions were rewritten so as to assume no prior engineering knowledge and to make them linguistically simpler. The same Time 1 and Time 2 assessment process was followed, making sure that the students' teachers or adult coaches had no knowledge of a student's individual performance. In our second year, we will use the materials generated from the first year to place this course online, as well, so students beyond the scope of our reach at other universities, high schools, and private locations like MakerSpaces can also participate. We plan to put the assessment online for these individuals, although assume that the retention rate may decrease as compared to the in-person courses.

Attitude Assessment – At the end of the knowledge assessment, we included an attitude assessment developed inductively [19] and validated through engineering service learning courses at TTU [20]. The text of this assessment can be found in [19], but it was developed through focus groups of undergraduates telling us what skills they believe are increased in their undergraduate engineering courses, particularly courses that have a community outreach component (like this one). Students are asked to rate (on a 1-5 scale) the importance for engineers of 11 discrete skills like time management, leadership skills, technical skills, etc. Then, they are asked to rate themselves on those skills – again, on a 1-5 scale. At the end of the semester, they are asked to do the same, with the addition of a third column that asks them if they've improved over the course of the semester on that skill. We found that this column is actually quite important, in that many students actually rate themselves lower on a given skill at the end of the semester than in the beginning, but simultaneously say that they have improved. Analysis of why this might occur can be found in the results section below.

Data – In the first year, we received 69 assessments at the beginning of the semester (20 from TTU, 25 from KSU, and 24 from CSUN) and were able to match them with YY assessments at Time 2 (the end of the semester). This resulted in a total valid-pair rate of ZZ%. We hypothesize that the unmatched assessments are either due to absence the first or last week of class or dropping the course.

We received DD assessments from the local high schools or MakerSpaces working with us at Time 1 and EE assessments at Time 2, with a total valid-pair rate of FF%.

<u>Assessing Undergraduate Knowledge about Additive Manufacturing</u>

Table 1 contains information about the assessment of undergraduate knowledge at Times 1 and 2.[1] Overall, at Time 1, students averaged 15.62 on a 45-point scale (2 points per multiple choice

[1] Note to ASEE draft reviewers: we will fill in Time 2 in May, when we receive the data. This will be ready in time for the June conference.

question, 5 per essay question) with a standard deviation of 6.04. There were 10 multiple choice questions and five essays questions. Using an ANOVA, we determined that there is not a difference in baseline knowledge between universities ($F=3.14$, $p=.42$). This may be due to low sample sizes and will be rechecked in future years with a larger sample size.

Table 1: Content Knowledge Averages and Differences at Times 1 and 2, by University

	Time 1	Time 2	Change
TTU	N=20, $\bar{X}$=15.55	N= TBD, $\bar{X}$ =	XX matched pairs, TBD
KSU	N=25, $\bar{X}$ =17	N=, $\bar{X}$	YY matched pairs, TBD
CSUN	N=24, $\bar{X}$ = 14.25	N=, $\bar{X}$	ZZ matched pairs, TBD
Aggregate Total	**N= 69, $\bar{X}$ =15.62**	**N=, $\bar{X}$ =**	**AA total matched pairs, TBD**

We also collected data by demographic characteristics, like race, gender, major, and whether the student reported being a first-generation college student. In Table 2, we can see that the reported numbers for male and female students, Industrial vs. Mechanical Engineering majors (our only two reported majors), and between whites and non-whites. We do have disaggregated data for non-white students (8 are Asian, 9 are Hispanic, and 5 are African American), but the test loses its statistical power due to low sample size when the races are treated separately. Some students chose not to disclose their sex, gender, or other demographic information, so they have been left out of the below analysis.

Table 2: Content Knowledge Averages and Differences at Times 1 and 2, by Demographics

	Time 1	Time 2	Change
Males (Time 1 N= 50)	$\bar{X}$= 15.6	$\bar{X}$ =	XX matched pairs, TBD
Females (Time 1 N=18)	$\bar{X}$ = 15.94	$\bar{X}$ =	YY matched pairs, TBD
Industrial Engineering (Time 1 N= 40)	$\bar{X}$ = 16.03	$\bar{X}$ =	ZZ matched pairs, TBD
Mechanical Engineering (Time 1 N=11)	$\bar{X}$ = 20.82	$\bar{X}$ =	AA matched pairs, TBD
White Students (Time 1 N=43)	$\bar{X}$ = 16.74	$\bar{X}$ =	BB matched pairs, TBD
Non-white Students (Time 1 N= 23)	$\bar{X}$ = 14.3	$\bar{X}$ =	CC matched pairs, TBD
First Generation College Students (Time 1 N=18)	$\bar{X}$ =13.22	$\bar{X}$ =	DD matched pairs, TBD

Non-First Generation College Students (Time 1 N=50)	$\bar{X} = 16.58$	$\bar{X} =$	EE matched pairs, TBD

Using two-sample t-tests, we compared by gender, major, and race at Times 1 and 2. At Time 1, we determined that there are not statistically significant differences between males and females (p=.879), are not statistically significant differences between IE and ME majors (p=.257), and are not statistically significant differences between whites and non-whites (p=.363). Time 2 data, as well as data about changes over time, will be available in May for the June conference.

<u>Assessing Undergraduate Attitudes towards Engineering and Their Own Skills</u>

Attitudinal metrics rest on the assumption that one's perception about one's own skills and the utility of those skills in one's profession matter. This assumption is not unfounded: social cognitive theory, originated by Bandura [21], holds that one's perception of one's own skill level is directly affected by interactions with others, in which one can both learn new knowledge or skills and compare one's own knowledge and skill attainment with the surrounding cohort. Thus, learning is a recursive and interactive process, not only with others, but through continual assessment of one's own mastery level. Indeed, that assessment of one's own knowledge and skills is instrumental for both persistence at a given problem and task. If a person feels like s/he is progressing in knowledge or skills, then persistence at a task will increase. This may be especially true when the individual particularly values the knowledge or skills in which s/he is progressing.

This is to say that the students' assessment not only of their own skills is important, but also that we should expect them to pay more attention to those skills or qualities that they think are important for engineers to have. Thus, as mentioned above, we asked them both to assess their proficiency (on a five-point Likert scale) at a given set of skills previously found to be important to engineers by other undergraduates and to also rate how important they considered those skills. This assessment is called the *Engineering Skills Assessment* (ESA) [19]. Thus, at Time 2, we will be able to test whether they improve more in those skills that they consider to be more important, as previous research would indicate. As mentioned above, at Time 2, we also added a third column that asked students whether they had improved at a given skill. Since students don't have access to their original ratings from Time 1 during the Time 2 assessment, this was an additional check to see whether any numerical change matched with the student's own perception of skill change. While we won't have these data until Time 2, it will be interesting to see whether the verbal matches the numerical.

Tables 3 and 4 (found in Appendix B) display the attitudinal differences both in what students considered important to engineering and their self-assessment of those same skills. We grouped students by university to determine whether there were any meaningful differences between universities. Using an ANOVA, for what students consider important to engineering and using $p \leq .05$, we determined that there are no statistically significant differences between schools for job related skills (F=.334, p=.72), no statistically significant differences between schools for interpersonal skills (F=.362, p=.71), and no statistically significant differences between schools for life/professional skills (F=1.6, p=.28). For their self-assessments and using $p \leq .05$, we determined that there are no differences between schools for job related skills ($F=3.57$, $p=.06$), no statistically significant differences between schools for interpersonal skills ($F=2.64$, $p=.15$), and no statistically significant differences between schools for life/professional skills ($F=4.65$, $p=.06$). It is possible that low sample sizes are causing the lack of statistical differences between schools and this may change given data collection in future years.

Assessing Secondary Students' Knowledge and Attitudes

At the time of this draft, data about secondary students are unavailable, since their module starts about halfway through the undergraduates' course. We will update this for the conference when data are available.

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Appendix A – Content Knowledge Metric

(1) Which kinds of materials can be fabricated by additive manufacturing processes (more than one answer)?
(A) Metals (B) Ceramics (C) Plastics (D) Composites

(2) 3D printable models may be created with a computer-aided design (CAD) package, and __________ is one of the most common file types that all the 3D printers can read and print.
(A) .sldftp (B) .dwg (C) .stl (D) .cad

(3) Which one of following processes used filament as starting material (feedstock)?
(A) Fused Deposition Modeling (FDM) (B) Selective Laser Melting (SLM)
(C) Stereolithography (SLA) (D) Laser Engineered Net Shaping (LENS)

(4) Which one of following processes would not be used in additive manufacturing fabrication?
(A) Extrusion (B) Fusion welding
(C) Polymerization (D) Machining

(5) Which of the following process has the lowest unit manufacturing cost?
(A) Fused Deposition Modeling (FDM) (B) Selective Laser Melting (SLM)
(C) Stereolithography (SLA) (D) Laser Engineered Net Shaping (LENS)

(6) You can recycle many plastic containers and extrude them into reels of filament used on Fused Deposition Modeling (FDM) 3D printers. These plastics are __________.
(A) thermoplastics (B) thermosets (C) photopolymers

(7) In 2015, the FAA cleared the first 3D printed part to fly in a commercial jet engine from GE. It is the housing for the compressor inlet temperature sensor as shown in this right figure. By layering powered metals that are melted and fused together through a process known as __________ the piece are welded together as one and come out five times stronger than its predecessor.

(A) Selective Laser Melting (SLM)
(B) Fused Deposition Modeling (FDM)
(C) Stereolithography (SLA)
(D) Laser Engineered Net Shaping (LENS)

(8) Which of the following additive manufacturing solutions applies an ultraviolet light to a liquid polymer to change it into solid plastic?
(A) Selective Laser Melting (SLM) (B) Fused Deposition Modeling (FDM)
(C) Stereolithography (SLA) (D) Laser Engineered Net Shaping (LENS)

(9) Post processing ______________ be used after AM fabrication?
(A) has to (B) doesn't have to

(10) Generally speaking, the AM fabricated parts have better surface roughness than machined parts. Please judge this statement.
(A) True (B) False

(11) In your opinion, what is additive manufacturing or 3D printing?

(12) Please talk about how the part would be built from 3D model to 3D part in additive manufacturing processes?

(13) Discuss the current benefits and limitations of 3D printing; give examples of areas where 3D printing is perfectly fitting in and some are not niche markets now.

(14) Current AM/3D printing technologies all build a part in a layer-by-layer fashion. Do you think it is the perfect way to build every part? What can you imagine as a “true AM/3D printing technology”, why it is better than the state-of-the-art now?

(15) Biofabrication is strongly reliant on 3D printing to accurately place cells, matrix and materials in position for tissue engineering. These constructs can be used as testing systems for new drug discovery, understanding cell biology and for replacing tissues and organs that are damaged through injury or disease. As you can image, bones, tissues, and organs, especially for a specific individual, cannot be drawn easily using an engineering CAD package, can you think of any approach to generate these digitalized and individualized 3D printable files?

Appendix B

IMPORTANCE TO ENGINEERING		Time 1				Time 2*				Change*			
		TTU N=20	CSUN N=24	KSU N=25	TOTAL	TTU	CSUN	KSU	TOTAL	TTU	CSUN	KSU	Total
Job Related Skills	Analytical Skills	4.45	4.5	4.36	4.44								
	Computer/Technical Skills	3.8	4.43	4.24	4.16								
	Math/Science Skills	4.35	4.3	4.32	4.32								
	Creativity	4.15	4.36	4.08	4.2								
	Problem Solving	4.8	4.64	4.76	4.73								
	Overall Job Related	*4.31*	*4.45*	*4.35*	*4.37*								
Interpersonal Related Skills	Leadership	4.2	4.43	3.82	4.15								
	Communication	4.5	4.82	4.64	4.65								
	Teamwork	4.55	4.52	4.68	4.58								
	Overall Interpersonal	*4.42*	*4.59*	*4.38*	*4.46*								
Life and/or Professional Skills	Time Management	4.35	4.52	4.48	4.45								
	Orderliness and Organizational Skills	4.05	4.68	3.72	4.15								
	Attention to Detail	4.4	4.89	4.68	4.66								
	Overall Life/Professional	*4.27*	*4.7*	*4.29*	*4.42*								

* Data to be added by conference time.

	Time 1	Time 2*	Change*

SELF-ASSESSMENT		TTU N=20	CSUN N=24	KSU N=25	TOTAL	TTU	CSUN	KSU	TOTAL	TTU	CSUN	KSU	Total
Job Related Skills	Analytical Skills	4	4	3.6	3.87								
	Computer/Technical Skills	3.4	3.86	3.4	3.55								
	Math/Science Skills	3.85	3.86	3.64	3.78								
	Creativity	3.25	4.3	3.8	3.78								
	Problem Solving	4	4.12	3.76	3.96								
	Overall Job Related	*3.7*	*4.03*	*3.64*	*3.79*								
Interpersonal Related Skills	Leadership	4.15	4.14	3.72	4								
	Communication	4.05	4.14	4.08	4.09								
	Teamwork	3.9	4.33	4	4.08								
	Overall Interpersonal	*4.03*	*4.2*	*4.17*	*4.13*								
Life and/or Professional Skills	Time Management	4.1	4.16	4.16	4.14								
	Orderliness and Organizational Skills	3.85	4.37	3.6	3.94								
	Attention to Detail	3.75	4.48	3.76	4								
	Overall Life/Professional	*3.9*	*4.37*	*3.84*	*4.04*								

* Data to be added by conference time.