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Project IMPACT: A Case Study of Developing a Manufactured Construction Workforce through Contextualized Training

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With a looming shortage of skilled craft workers forecast to exceed 2 million by 2017, prefabrication may become a necessity for many U.S. contractors attempting to remain competitive with a smaller, lower-skilled workforce. Building components manufactured in a controlled, offsite environment have proven to reduce time, cost and site logistics while improving productivity, quality, safety and sustainability. However, entry-level workers, including more than 765,000 recession displaced manufacturing workers, often lack the basic skills necessary to retrain for jobs in manufactured construction. As a result, a \$ 6.3M U.S. Department of Labor grant was awarded to an *institutional consortium* to develop online, contextualized training in manufactured construction and related manufacturing industries. Of more than 1,020 participants from 2012-16, learning outcomes from a focus group of 70 participants were statistically analyzed to compare the effectiveness of *contextualized* training among non-traditional student cohorts (e.g. older adults, veterans, women, minorities, etc.). Results indicate that graphic oriented, online training used in conjunction with traditional instruction, improved access and learning outcomes particularly among older adults, ethnic minorities and women.

Key words: contextualized training, workforce development, manufactured construction

Introduction

Manufactured Construction

Manufactured construction refers to the fabrication and assembly of building components at a location other than the construction site. This ‘pre’ fabrication of building elements may consist of simple component assemblies such as pipe racks and wall panels to complete building modules (Figure 1). Manufactured construction has proven to reduce construction time, project cost and site logistics while improving productivity, quality, safety and sustainability (e.g. reduced site materials and waste). Manufactured construction is most often used on projects where repetitive building units and mechanical, electrical and plumbing (MEP) systems are common, such as hospitals, office buildings and hotels (MHC, 2011). According to the National Institute of Building Sciences (NIBS), more than 90% of U.S. contractors utilize some form of manufactured construction (Smith, 2014) with nearly two-thirds (65%) reducing project costs an average of four percent.

Among U.S. contractors utilizing offsite prefabrication, 92% cite productivity and the shortage of skilled craft labor as the primary reasons for doing so. According to an AGC-SmartBrief to attendees of the 2016 ASC International Conference, 25% of firms have passed on projects because of worker shortages, with 69% of contractors indicating craft worker shortages will remain or get worse over the coming 12 months (AGC, 2016). Manufactured construction has the potential to offset a shortage of skilled craft workers with a smaller, lower-skilled workforce because these workers can quickly learn entry-level job skills, reinforced by repetition, in a controlled environment. Yet, one-third of U.S. contractors cited skills and training as a barrier to using offsite construction (MHC, 2011) due in part to an entry-level workforce increasingly comprised of older adults, women and minorities who lack basic skills and are unable to acquire these skills through traditional delivery systems. In fact, 45.1% of the post-recession

construction workforce is now women and minorities with 60% or more women and minorities working in offsite construction and related manufacturing industries (BLS, 2016).

As a result, new approaches are needed to provide effective craft training customized to the adult learner, and, flexible support for nontraditional students who must balance work-life demands with limited educational opportunities (Rademacher, 2002). The National Center for Education Statistics defines nontraditional students as those who delay enrollment into postsecondary education, attend college part-time, work full time, are financially independent for financial aid purposes, have dependents other than a spouse, are a single parent, or, do not have a high school diploma.



Figure 1. Prefabricated building modules and MEP pipe racks (Smith, et al., 2015)

Contextualized Training

Many entry-level construction workers have not been in a structured learning environment or used high school equivalency skills in several years, if at all. Most have difficulty understanding basic academic concepts needed for craft training such as measurement and geometry that are traditionally taught in a classroom setting. Contextualized teaching and learning (CTL) is a strategy that engages adult learners and promotes improved skills development by helping instructors relate subject matter content to real world situations (Berns and Erickson, 2001). According to contextual learning theory, learning occurs only when students process new information in such a way that it makes sense to them and appears useful. Too often, however, remedial math skills are taught independent of, or, as a prerequisite to occupational training, resulting in adult learner discouragement and high training program attrition rates. CTL blends both basic skills and occupational training together in environments that allow students to visualize relationships between abstract ideas and practical applications. CTL has proven particularly effective for adult learners who value short, hands-on instructional segments where they can relate new skills to real-world experiences (Killingsworth, 2012). A primary principle of CTL is that knowledge becomes the students' own when it is learned within the framework of an authentic context (Baker, et al., 2009).

One of the main goals of CTL is to develop authentic craft training tasks to improve student learning outcomes and assess performance. Since actual hands-on craft training can be time consuming, expensive and potentially dangerous for entry-level workers, technology enabled training using interactive, virtual environments can complement traditional entry-level training. Using 4D game-based technologies, virtual manufactured construction environments can be created, and, both basic and occupational training tasks integrated together in simulations that engage the student and provide immediate performance feedback (Figure 2). Virtual training can also be internet accessible, supporting online and distance education necessary to reduce training time and cost while improving accessibility, especially for non-traditional students. The virtual environment provides students with problem solving within realistic situations, learning in multiple contexts, content derived from diverse work and life situations, and authentic situations in which the skills will be used (Svinicki, 2004 and Baker et al., 2009).



Figure 2. Online contextualized training for manufactured construction using 4D simulation.

Project IMPACT

To address the aforementioned workforce development challenges, a \$6.3M U.S. Department of Labor grant was awarded to an institutional consortium to develop online, contextualized training for manufactured construction and related manufacturing industries. This project, called 'IMPACT' (Innovations Moving People toward Certified Training), consisted of a consortium of five (5) Midwest community colleges providing entry-level occupational training and certification, and, a university partner specializing in contextualized curricula development and advanced visualization technologies for adult basic education (ABE). Together, this consortium developed an entry-level training program for manufactured construction as part of a new *Diversified Manufacturing Technology (DMT)* certificate which provided 12 credit hours of training in basic *safety, quality control, production and maintenance*. The curriculum was aligned with the *Manufacturing Skill Standards Council (MSSC), Certified Production Technician (CPT)* program, a nationally recognized certification transferable across a broad spectrum of U.S. manufacturing industries, including manufactured construction. Articulation agreements were also developed to credit DMT certificate courses to more advanced levels of training and education including 30 credit-hour (1-year) diplomas and 60 credit-hour (2-year) associate degrees, which could be transferred to 4-year degree programs. As a result, the program provides participants access to both continuing education and employment (Figure 3).



Figure 3. Project IMPACT 'on' and 'off ramps' between continuing education and employment.

The overall goal of Project IMPACT was to build workforce capacity in manufactured construction and related manufacturing industries as evidenced by training program completions, earned credentials, sustained employment and higher wages for more than 1,000 participants from 2012-2016 (Table 1).

Table 1

Project IMPACT participant learning outcomes and employment status, 2012-2016.

Aggregate Project Outcome Measures	Actual	Planned	+/-
1. Participants served or enrolled	1,020	838	182
2. Completed grant-funded program of study	279	590	(311)
Incumbent workers	177	-	-
3. Retained in grant-funded program of study	291	167	124
4. Retained in other programs of study	31	-	-
5. Total aggregate credit hours completed	32,179	-	-
Total number of students completing credit hours	904	728	176
6. Total number of earned credentials	713	789	(76)
Total number of earned credentials (<1 year)	141	-	-
Total number of earned credentials (≥1 year)	9	-	-
Total number of earned degrees	305	-	-
7. Total number pursuing higher education after completion	84	143	(59)
8. Total number employed after completion	111	447	*
9. Total number retained in employment after completion	76	402	*
10. Total number receiving wage increase after completion	80	280	*

* 406 students still active in program; total outcomes TBD.

Of 1,020 participants, 383 (37.6%) were women, ethnic minorities, military veterans or 'other' (e.g. disabled). The majority were non-traditional students (average age of 25.8) employed full-time (66.1%) or part-time (23.4%) upon enrollment. A total of 103 (10.1%) earned community college certificates, 471 (46.2%) earned industry certificates, and, 170 (16.7%) earned associates degrees. Industry certifications were found to be positively correlated with the number of IMPACT courses completed ($r=.570$; $p<.001$). Differences in average entry-level wages were also found to be positively correlated among IMPACT participants (\$2,165/month) compared to non-IMPACT participants (\$1,915/month) although one-third of IMPACT participants received starting wages in excess of \$3,000/month. The focus of this research paper, however, is to present evidence of the effectiveness of contextualized instruction to improve learning outcomes, particularly among older adults, women and minorities participating in Project IMPACT. A total of 625 (61.2%) of IMPACT participants were exposed to contextualized instruction using an online, interactive training software (*'Tooling U'*) with supplemental remediation materials and virtual reality training exercises. Preliminary results indicate that online, contextualized training used in conjunction with traditional classroom and lab or shop instruction, significantly improved access and learning outcomes particularly among older adults, ethnic minorities and women. The methods used to develop and deliver contextualized training to this audience, and, detailed results of this effort will be discussed in the sections to follow.

Methods

Training Interventions

Tooling U-SME

To determine the effectiveness of contextualized instruction to improve learning outcomes among non-traditional entry-level workers, the *Society of Manufacturing Engineers (SME) Tooling U* curriculum and learning management system (LMS) was used. The Tooling-U curriculum consists of 414 online, bilingual (English and Spanish) course modules with interactive exercises, 99 with interactive labs, and 37 modules with 4D simulations. Tooling U modules are designed to provide foundational skills in 22 manufacturing related areas at three (3) competency levels (100-intro, 200-intermediate and 300-advanced) in a *shareable content object reference model (SCORM)* format. For the MSSC-aligned DMT certificate, 82 contextualized Tooling U modules were selected in the core areas of *safety*,

quality control, production and maintenance; 53 with basic skills remediation, 28 with interactive labs and 14 with virtual reality (VR) exercises.

In addition to the curriculum, Tooling U provides a learning management system (LMS) to track individual student performance and determine the effectiveness of contextualized instruction to improve learning outcomes. Among the most important LMS metrics used are pre and post test scores for each course module. In addition, the LMS tracks course completions, time spent on each course module and many other performance factors that can be assigned to individuals or cohorts of individuals in a specific class or demographic group. From this information, differences in competency levels for incoming students can be normalized and skills attainment through the Tooling U training intervention more accurately measured.

Basic Skills Development and Integration Guide

In addition to the Tooling U curriculum and LMS, 126 foundational skills exercises were developed as supplements to the 82 Tooling U course modules. Exercises developed included 76 contextualized reading comprehension and writing exercises for 100-level introductory courses in *production* and *maintenance*, and, 50 contextualized math exercises for 100-level introductory courses in *safety* and *quality control*. These supplementary materials were embedded within several Tooling U course modules for adult learners who required remediation in number operations (e.g. decimals, fractions, percentages, etc.), measurement, geometry, reading comprehension or written communications prior to completing the course module.

Interactive VR Simulation Exercises

Ten (10) virtual reality (VR) training exercises were also developed to reinforce contextualized instruction and assess performance. Each interactive exercise consisted of an intermediate-level task assignment supported by 4D simulations and embedded videos of a 4-6 step fabrication process. Each exercise required the student to 1) read and interpret shop drawings, 2) select proper tools and equipment, 3) layout materials and 4) fabricate building or MEP systems components (Figure 4). In addition to reinforcing instruction and assessing student performance, VR simulations were also used to address the negative public perception of manufactured construction (e.g. low-tech, dirty and dangerous) and recruit both traditional and non-traditional students into the DMT program. (Standridge, 2001).

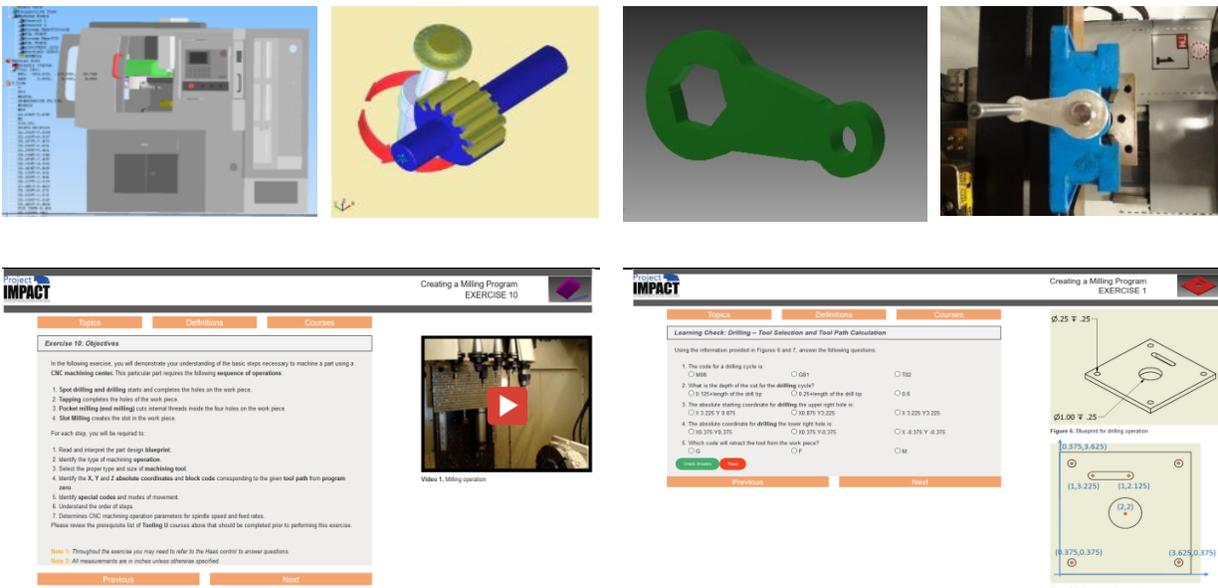


Figure 4. Sample 4D simulation of MEP component fabrication exercise.

Together with the Tooling U curriculum, the VR exercises were designed to simulate manufactured construction environments and interactive prefabrication tasks to 'bridge' the transition between classroom and shop instruction for a more efficient and safe training experience.

Training Cohort

Participant data for more than 1,020 participants from five community colleges was entered into a database upon enrollment and updated quarterly from 2012-16. Participant data included student demographics, learning outcomes, and, post-training employment status (Table 2). A total of 281 students from Metropolitan Community College (MCC) were screened for further study. Of these, 70 students exposed to the contextualized Tooling U curriculum were selected as the *experimental group*. Learning outcomes such as pre and post-test scores, course completions and other performance factors within the experimental group were correlated to participant demographics and compared to non-Tooling U participants (*control group*) to determine the effectiveness of *contextualized* training, particularly among non-traditional student cohorts. This experimental group was used as a 'pilot' study to evaluate assessment methods for the IMPACT project. The study design was considered quasi-experimental since participants and training interventions were not randomly selected.

Table 2

Project IMPACT participant database.

Demographics	Learning Outcomes	Employment Status
Gender	Tooling U pre-test scores	Employed
Age	Tooling U post-test scores	Retained in employment
Ethnicity	Tooling U modules completed	Wage increase
Employment status	DMT credit hours completed	Pursuing further education
Veterans status	Retained in IMPACT program	
Disability	Retained in other program	
Financial need	Certificate(s) earned	
Scholarship eligibility	Diploma(s) earned	
	Degree(s) earned	

Results

Of 70 students included in the pilot study, 23.4% were female compared to 7.2% for all project IMPACT participants. The average age of pilot study participants was 42 years compared to 26 years of age for all participants. Ethnic minorities composed 37.8% of students in the pilot study compared to 22.2% for all project participants. The employment status of all project IMPACT participants was 66.1% full-time and 23.4% part-time, respectively. Veterans comprised 23.2% of pilot study students compared to 8.8% for all project IMPACT participants. Overall, the pilot study cohort was significantly more representative of the non-traditional student audience when compared to all project participants.

Within the experimental group, a total of 3,108 Tooling U modules were completed. Of these 1,133 (36.5%) modules were completed by 44.2% of participants scoring less than 60% on module pre-tests (49.2% average). By comparison, nearly twice the number of Tooling U modules (1,975) were completed by the other 55.8% of participants scoring 60% or above on module pre-tests (66.7% average), suggesting that prior training and experience was a factor in successfully completing course modules. Similarly, 794 (25.5%) of modules were completed by 31.7% of participants scoring 60%-80% on module *post*-tests (75.3% average). By comparison, roughly three times the number of Tooling U modules (2,299) were completed by 68.3% of participants scoring above 80% on module *post*-tests (89.1% average) suggesting that significant improvements between total average pre-tests (59.5%) and total average *post*-tests (83.5%) occurred as a result of the contextualized Tooling U training curriculum, including participants who did not appear to have prior training and experience related to manufactured construction. In fact, participants achieving a 20% or greater improvement between Tooling U pre and *post* test scores were more than twice as likely to complete credit hours toward a DMT credential (e.g. certificate or degree).

Within the experimental group, male participant pre-test scores (60.1%) were slightly higher on average than female pre-test scores (57.5%) although Tooling U post-test scores were the same on average for both groups (83.1%). As a result, female participants achieved an average 25.6% improvement between pre and post-test scores compared to a 23.0% improvement for males. Furthermore, female participants achieved *significantly* higher rates of module completion (101.7) on average than males (63.3). Participants older than 45 scored higher on pre-tests (62.3%) than participants age 45 and under (57.4%). Participants older than age 45 also scored higher on Tooling U post-tests (86.7%) than participants age 45 and under (81.1%). Participants older than age 45 achieved a 24.3% improvement on average between pre and post-test scores, second only to the 25-35 age group (26.5%). Participants older than 45 achieved *significantly* higher rates of module completion (84.7) than age groups < 25 (45.8), 25-35 (74.3), and, 36-45 (59.7) respectively.

Black participant pre-test scores (56.4%) were lower on average than either Hispanic or Caucasian pre-test scores (60.4% and 60.2% respectively). Black participants also scored lower on Tooling U post-test scores (81.5%) compared to Hispanic and Caucasian participants (83.7% and 85.1% respectively). Black participants, however, realized the greatest improvement on average between pre and post test scores (25.1%) compared to Hispanic and Caucasian participants (23.2% and 24.9% respectively). Hispanic participants, however, achieved *significantly* higher rates of module completion (93.9) on average than either Black or Caucasian participants (70.3 and 71.2 respectively). Veterans scored higher on pre-tests (65.4%) than any other demographic group and higher on Tooling U post-tests (85.5%) than all other demographic groups except participants older than 45 (86.7%). Disabled participant pre-test scores (61.4%) were higher on average than non-disabled participant pre-test scores (59.1%). However, disabled participant post-test scores (82.7%) were slightly lower than non-disabled participant post-test scores (83.7%). As a result, disabled participants realized a 21.3% improvement on average between pre and post-test scores compared to a 24.6% improvement for non-disabled participants.

Participant employment and wage outcomes data was maintained separate of the project IMPACT grant by the state Department of Labor (DOL). The DOL was able to provide only aggregate employment and wage data that could not be associated to individual participants or demographic cohorts.

Discussion

Manufactured construction has the potential to offset a shortage of skilled craft workers with a smaller, lower-skilled workforce. Yet, skills and training remain a barrier to using offsite construction as the entry-level workforce is increasingly comprised of older adults, women and minorities who lack basic skills and are unable to acquire these skills through traditional delivery systems. As a result, a contextualized training program was developed to provide greater access and more effective craft training for non-traditional students. Major findings of this study include:

- Participants achieving a $\geq 20\%$ improvement between Tooling U pre and post test scores were more than twice as likely to complete credit hours toward a certificate or degree.
- Female participants achieved a 25.6% improvement between pre and post-test scores on average compared to a 23.0% improvement for males. Female participants achieved higher rates of module completion (101.7) on average than males (63.3).
- Participants older than age 45 scored higher on Tooling U post-tests (86.7%) than all other demographic groups and achieved higher rates of module completion (84.7) than age groups < 25 (45.8), 25-35 (74.3), and, 36-45 (59.7) respectively.
- Black participants achieved the greatest improvement between pre and post test scores (25.1%) compared to all other ethnic groups. Hispanic participants, however, achieved higher rates of module completion (93.9) on average than either Black (70.3) or Caucasian participants (71.2) respectively.
- Veterans scored higher on Tooling U post-tests (85.5%) than all other demographic groups except participants older than 45 (86.7%). Disabled participants, however, scored lower on post-tests (82.7%) and

achieved lesser improvement between pre and post-test scores (21.3%) on average compared to a 24.6% improvement for non-disabled participants.

Preliminary results indicate that contextualized training used in conjunction with traditional instruction, improved learning outcomes for all participants, especially among adults aged 45 years and older, ethnic minorities and women. Learning outcomes for disabled participants, however, were lower when compared to other non-traditional student cohorts and to the overall experimental group, a finding that will require further investigation. Limitations of this research include a relatively small pilot study population (n=70), particularly within subset demographic groups. Complete learning outcome and employment data will not be available until the IMPACT project concludes in 2017.

Conclusion

Preliminary results indicate that the contextualized learning approach of traditional instruction and technology enabled task simulation was effective in improving learning outcomes and assessing student performance. Together with enhanced vocational counseling and support (e.g. personal coaching, employability ‘soft’ skills training, physical and behavioral assessments, program and job placement, etc.), the IMPACT project was successfully able to recruit and enroll 1,020 participants, 20% above the program goal. Of these, nearly all were non-traditional students with significant work-life responsibilities outside of the classroom. Not only was the IMPACT project successful in providing greater access to these students through online and distance delivery, but also through the modular design of ‘stackable’ courses, credits and credentials that articulate toward higher education and higher wage earning potential. This design gives students ‘on and off ramps’ between continuing education and employment where they can pursue lifelong career development and advancement.

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