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Web-based virtual learning for digital manufacturing fundamentals for automotive workforce training

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Abstract: Automotive manufacturers are experiencing difficulties in hiring highly qualified workers with ability to adopt new technologies fast. This kind of ongoing need for training is slowing innovation. This problem is related to the difficulty in obtaining consistent training resources and services especially with lack of training for advanced manufacturing practices for specialised industry sectors. More and more occupations require degrees higher than secondary education because of the global need for so called 'knowledge workers'. An example of an interactive learning programme, developed with the support of narrated presentation technology, podcasts and online access has been shown in this paper. Sixty nine online modules have been developed during the course of a project funded by Department of Labor for automotive sector. These online modules have been developed for lifelong learners to be used and accessed at any time (asynchronously from a website). Curriculum modules, developed for the Introduction to Digital Manufacturing are a part of a certificate programme which expands the pool of skilled workers, enhance the abilities of incumbent workers, and strengthen the entire advanced manufacturing sector.

Keywords: lifelong learning; continuing education; web-based virtual learning; digital manufacturing; automotive industry.

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1 Introduction

One of the areas related to the advanced manufacturing sector is digital manufacturing. It is an emerging area within product lifecycle management (PLM) that supports collaboration across several phases of product lifecycle (Grieves, 2006; Haydaya and Marchildon, 2012; Luh et al., 2011). It is based on the current Computer Aided Manufacturing (CAM) software solutions that are often included in modern engineering and manufacturing IT infrastructure which encompass product development, manufacturing, inspection and control. As mature CAM technologies are approaching the point of diminishing returns, digital manufacturing promises the next leap in enterprise development to enable innovation and improved product development (Kolawa, 2009; Lee et al., 2011; Ameri and Patil, 2012). It allows holistic approach to product design and process planning through exchange of information across numerous stakeholders for the benefit of the entire enterprise (Mital et al., 2008). This technology provides numerous benefits including reduced time-to-market and reduced development and manufacturing costs (Wang, 2011).

Adult learners frequently need to improve their skills because of a competitive workforce of today in order to advance on a labour market and improve their standard of living (Choitz and Prince, 2008). Moreover, they have considerably different needs than traditional college students while earning their postsecondary credentials. In addition, they have different challenges related to work responsibilities, family obligations, all related to a need to a more flexible design and delivery methods that recognise the time constraints facing people who work, have family responsibilities and are trying to upgrade their skills to be more competitive in the labour market and improve their standard of living.

The percentage of working-age adults in the workforce who have a credential beyond a high school diploma is less than 40% (Kazis et al., 2007). The number of adults in postsecondary education is rising in recent decades. However, their success rate is still too low (Alfred, 2010). Some alternative approaches for delivering postsecondary education to meet the needs of adult learners are recently being considered (Day et al., 2011). Those are: more flexible course scheduling (weekend, evening) and location (satellite campuses, on-site at the workplace), flexible course and programme design (modular, open enter/open exit), and distance learning (Ritt, 2008).

Postsecondary education providers are developing different online delivery mechanisms to increase adult access to courses, all for a purpose of shorter time needed to earn a degree (Choitz and Prince, 2008) and often with a focus on people currently working in the field. For this purpose, they are teaching classes at different times which are more convenient to adult learners (Grable, 2011; Smith, 2011). In addition, they try to reach out to learners throughout a delivery in non-traditional locations (Kazis et al., 2007). To achieve these new methods of approach, they are not changing the essence of the course. Moreover, they are adding online components and delivering segmented lectures through shorter modules (Ross-Gordon, 2011). Sometimes the whole programme is completely redesigned to meet these needs for easier, more modular access in online learning environment (Day et al., 2011). However, many institutions are still using combination of online and face to face delivery through blended learning teaching strategies for more flexible and accessible programmes which would result in better student achievement (Ausburn, 2004; Grable, 2011). Therefore, up to date training and education recourses are required to support the changing nature of employment in the USA from lower-skilled, high wage manufacturing jobs to newer requirements focusing on advanced technology and higher skills.

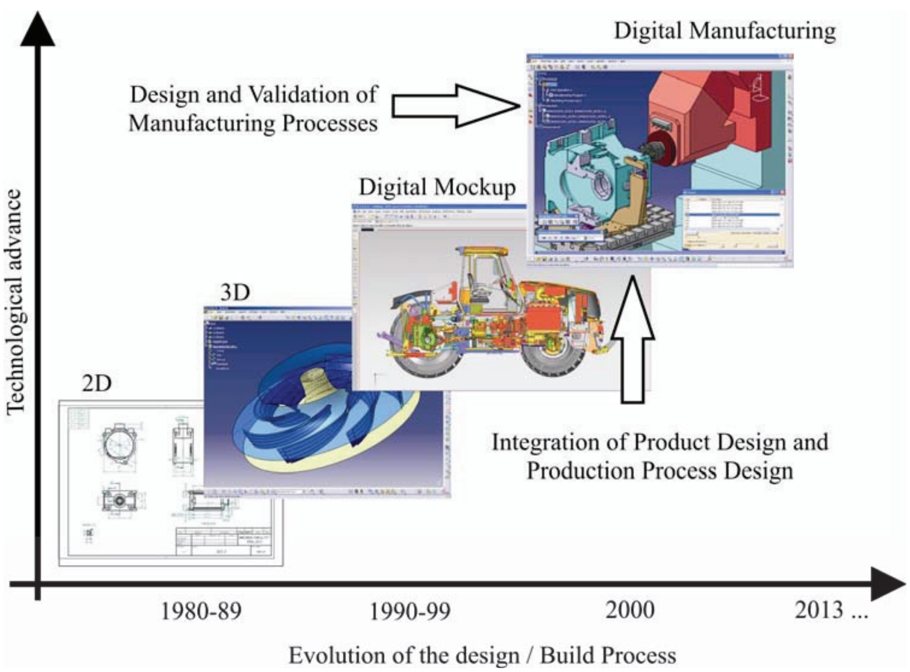
2 Digital manufacturing

Digital Manufacturing is an emerging area within PLM that supports collaboration across several phases of product lifecycle (Jovanovic et al., 2008). It is based on the current CAM software point solutions that are extended through emerging informational technology (IT) infrastructure to encompass product development, manufacturing and inspection and control.

Digital manufacturing supports collaboration across several phases of product lifecycle. Companies that are distributed can collaborate more easily and cheaper than before. It is important to enable collaboration among different parts of a digital enterprise. Design engineers have to have communication with the manufacturing and assembly personnel. They also have to know what is happening after the product leaves the company. It is necessary to collect information from the people that are dealing with the customers in order to improve products.

The technology that exists today is enabling the usage of analysis and simulation in order to optimise product and processes before the actual production and assembly. Virtual prototypes can also be used to verify does the product comply with the customer requirements (Gîrbacia et al., 2012; Zhiyong et al., 2012). Manufacturing has to be aligned with the design activities. Digital manufacturing enables production planning while design phase is still not finished (Kuo and Wang, 2012). Limitations and constraints related to the production are enabling Six Sigma methodologies to be implemented in the design phase (Aksoy and Dinçmen, 2011). Designing the robust product involves using manufacturing and assembly-based information in early design stages (Lijuan et al., 2011).

Figure 1 Evolution of the design – build process (see online version for colours)



Digital manufacturing is a term that is related to wide spectrum of digital models and methods that are dealing with every aspect with PLM. It is basically integration among different tools used for product design (computer aided design, project management applications) and manufacturing (layout planning, ergonomics, simulations and other applications used for planning and process optimisation of a real company), as shown in Figure 1. It supports innovation by linking all manufacturing disciplines with product engineering including: process layout and design, process simulation/engineering and production management through manufacturing backbone that keeps all necessary updated files necessary for the overall product design and realisation.

Digital manufacturing consists of product design, process planning, time management and business applications, factory layout planning, ergonomics, production process simulation, PLM systems, analysis software, and CAM software. Digital manufacturing connects product engineering with manufacturing through: process design, process engineering and production management through manufacturing database with up to date information needed for innovative product design and realisation. Based on Siemens company methodology, it relates product, process, resource, and plant data, through process-oriented technology (Siemens, 2012). Digital manufacturing is the ability to describe every aspect of the design-to-manufacture process digitally, ideally in a real time (Parker, 2010).

Digital manufacturing supports effective collaboration among engineering disciplines through visualisation, simulation, ergonomic and human factors analyses, and optimisation tools (Christman, 2002). It does that through application of a holistic view of product and process design as integral components of the overall product life cycle and enables easier implementation of design changes in relation to overall process constraints and capabilities. Digital manufacturing provides product data management throughout the manufacturing planning process (Delmia, 2012).

3 Digital manufacturing training materials design

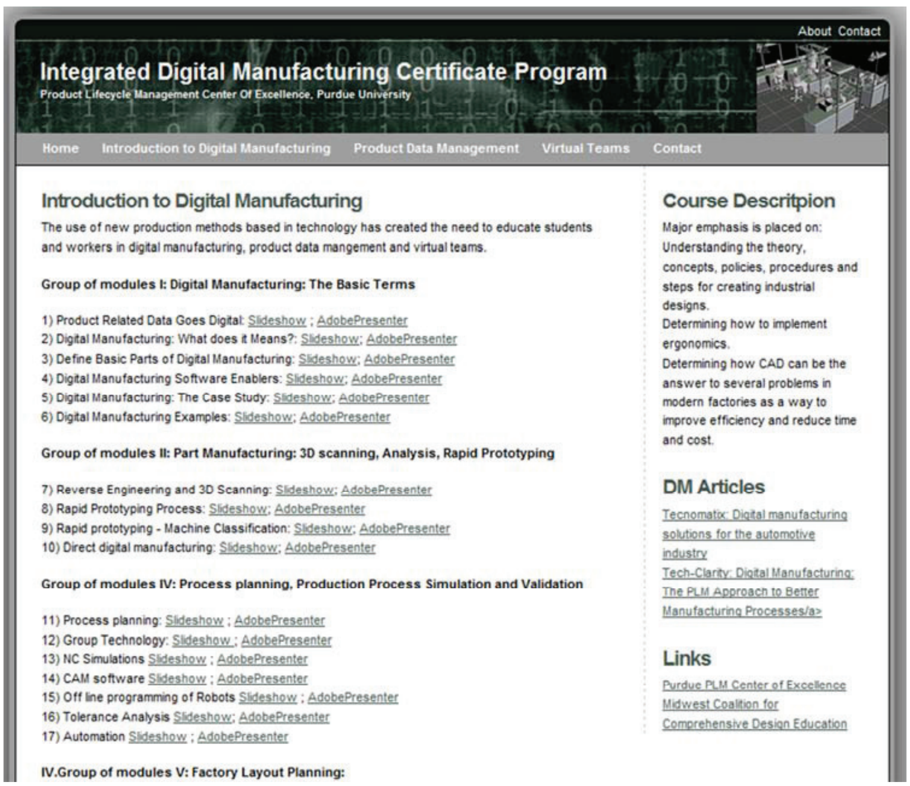
Online training materials have the potential to enable the incumbent workforce to have more flexible training options, and it helps them leverage their knowledge in order to advance in their current position or when moving to another transportation related company. The online materials are focused on the following objectives:

- The students should be able to understand what the product-related data is.
- Students should be able to understand the term ‘digital manufacturing’.
- Students should be familiar with the following terms: CAD, CAM, CAPP, factory layout planning, ergonomics, off-line robot programming, production process simulation, PLM systems, and analysis software.
- Students should learn which groups of software supports digital manufacturing.
- Understand the main digital manufacturing applications and review the case study of the successful application.
- The students should learn basic things about the process of reverse engineering and rapid prototyping. Overview of machine classification for rapid prototyping.
- Learn about virtual product design and ergonomics.
- Understand human factor and workspace design in digital environment.

- Students would be able to implement basic ideas related to the basic ergonomic analysis, human task analysis, and simulation in a virtual world.

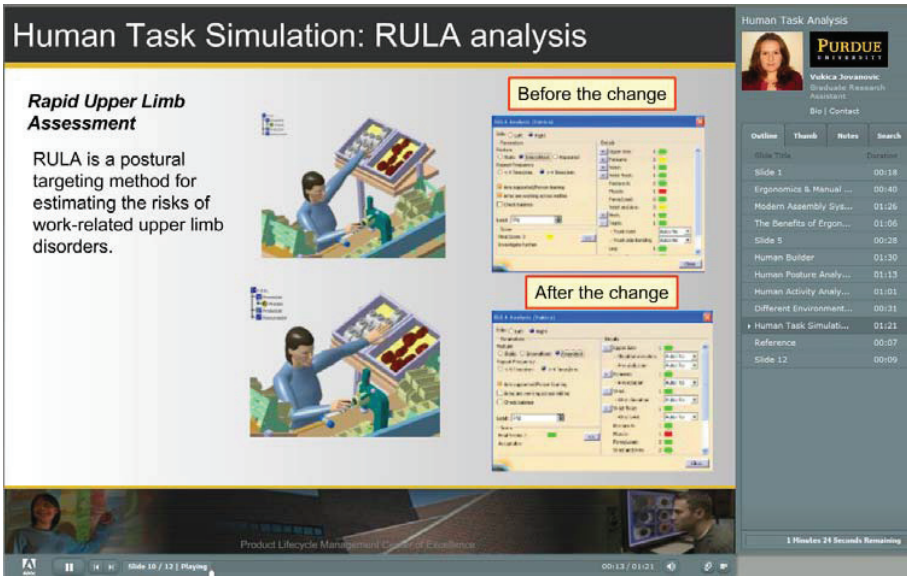
The curriculum modules developed during this project were adapted for online delivery to the employees in transportation-related manufacturing to move through career lattices-from foundation skills to post-graduate technical professional development. The modules were developed in the following formats: PowerPoint slideshows, Microsoft Word documents with the Learning plan, Adobe Presenter narrated presentations, MP3 and MP4 audio files suitable for podcasts and video file format suitable for iTunes and podcasts, as shown in Figure 2.

Figure 2 An example of access page to digital manufacturing learning modules (see online version for colours)



Learning plans developed for these modules had the following elements: overview/goal; competencies; pre-activity discussion; learning activity; assignment specifications; post activity discussion; assessment; references. Narrated presentations were created with the usage of text-to-speech conversion software. Approximate length of the modules was 15 to 20 minutes. Students can skip any part of presentation at any time with links given at the right hand side and move through presentation slides at any time, as shown in Figure 3.

Figure 3 An example of one training module: human task simulation (see online version for colours)



All modules are created as slideshows with the adequate teaching notes placed below the each slide. They could be used for giving the instruction related to the digital manufacturing. They also have a list of references. Presentations and podcasts (audio MP3 files that can be downloaded to iPod or mp3 player) have been created.

The training has to address the following considerations:

- *Reliability* – training should be validated by employers/employees and reflect widely accepted standards for competencies
- *Accessibility* – should be adapted to the needs of employers/employees in terms of schedule, format (modular), use of appropriate learning technologies (such as distance learning and podcasts), and accessible formats for working adults
- *Sustainability* – services within institutional framework so that it can be provided over a long timeframe.

The curriculum framework has to incorporate contextual learning, curriculum integration, seamless design, and inclusion of skill standards, competency assessment, and opportunities to exit and reenter programmes. The adoption of employability standards can help students transfer knowledge from school to work and understand the ways their education translates into usable skills, including creativity, problem-solving ability, and reasoning capacity. A quality occupational curriculum must provide multiple exit and reentry points for all students. Many may choose to go directly to work after high school, and to attend community college at a later time. Others will continue with school and obtain baccalaureate degrees, building on their technical foundation. The curriculum must be structured to accommodate these and other learners at various stages of programme involvement.

4 Findings

The external audit was performed at meeting at Purdue in October, 2008. The audit was focused on outcomes, gaps and efforts related directly to grant deliverables. This work was done by two Indiana University Purdue University Indianapolis (IUPUI) professors who have been sub-contracted by Ivy Tech Community College, who was also part of this project. This project was focused on the curriculum development, not delivery itself.

Ivy Tech Community College formed a curriculum subcommittee under the leadership of Advanced Manufacturing Careers Action Team which worked with researchers to develop this advanced manufacturing curriculum that could be delivered online to working adults and also aligned with existing baccalaureate programmes.

Developed modules were evaluated by Ivy Tech Community College. Training outcomes were measured with performance measures developed for the Indiana Strategic Skills initiative in 2005. They also were tracking enrolment, number of individuals completing courses and attainment of work credentials (in this case certificate of technical Achievement). They were then reported to Department of Workforce Development and Indiana Economic Development Corporation. Outcome measures for the service deliver y project are shown in Table 1.

Table 1 Outcome measurements for digital manufacturing certificate programme

Training outcome measures	*Solution projects (lead Ivy tech region)*		
	Location 1	*Location 2*	*Location 3*
Adult common measures			
Number of employed 1st quarter after exit	Exceeded state goal of 78 % for those exiting training, some sites maintained 100 %		
Number of retained in 2nd and 3rd quarters	Exceeded state goal of 83 % for those employed after the training		
Six month earnings increase	Exceeded state goal of $2,800 per person		
Community college measures			
Number enrolled	150	140	260
Completing training	135	115	234
Certified and/or degree	122	90	210

These modules were used by faculty at community colleges who were involved in this project. They were evaluating these modules after every project stage. The original modules were designed to be a full college lecture of one hour and 15 minutes. However, after the initial modules have been evaluated by the faculty from community college who are teaching in the area of advanced manufacturing, it was suggested that modules should be in a form of 10 to 15 minutes each. One of the reviewers suggested that podcasts should be evaluated as one of the possible delivery methods. Initial pilot podcasts have been developed but since not all people in our target audience is not using primarily that type of technology, researchers came up with the decision to develop standalone modules that could be accessed through regular website in a form of narrated presentations. One thing that users mentioned that they liked about these modules is that they could stop the narration at any time and browse from slide to slide to find the parts that they are the most interested in. The only issue that was important to review these modules is a need for reliable high speed internet connection since they are completely online and cannot be downloaded. Developed modules during this grant became a part of PLM centre knowledge base and they were further used and improved by faculty and graduate students. They were shared in form of slideshows that could be edited and reused.

5 Conclusions

During this project, curriculum for undergraduate engineering technology students and industry practitioners in the fundamentals of Digital Manufacturing was developed. It can be delivered either in person through on line delivery system or by listening and watching of podcasts and video casts. The first method, which is in person, can be implemented with the slideshows and Learning plans in through collaborative classroom management software. The second learning method would be focused on learning with already developed audio and video files can be used with smart phones. The employees could access those training modules at their own convenience. With modular approach that is being used for the development of those training modules, the students can create their own, customised training according to their needs.

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