The University's Role in Professional Development for Computer-Aided Engineering

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Abstract

This paper explores the need for workforce development for engineers interested in implementing Computer Aided Engineering (CAE) tools and describes a CAE Certificate program currently in the pilot phase of implementation. Workforce development is becoming a necessary component of the modern engineering workplace as technological advances such as CAE make the product development cycle more competitive. This requires working engineers to engage in lifelong learning to meet the needs of employers and to keep current with the available engineering tools in the workplace. Traditional graduate school includes barriers such as time commitment, travel, as well as program costs. These barriers limit access to graduate education particularly for those in the workplace who are not at liberty to take time away from work to attend classes and travel to a university campus. Typical educational resources in industry are often limited to short workshops and software training classes which focus on the use of the tool rather than its theoretical foundation and application to solve real-world engineering problems. While willing to invest in professional development for engineers, employers often lack experience in creating programs that both effectively develop CAE skills and help their engineers apply their new skills on the job. Programs specifically designed for working individuals can contribute to promoting continuous learning for so that their careers thrive and employers can remain competitive. This program will be assessed using a well-established evaluation framework in order to determine where improvements are needed to meet the needs of these adult learners.

Keywords

Professional development, life-long learning, online learning, Computer Aided Engineering

Introduction

Digital manufacturing is comprised of several tools including Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), and Computer Aided Engineering (CAE) [1]. The rise of digital manufacturing and the reliance on these technologies to reduce development time while improving product design and quality has been exponentially increasing over the past few year [2]. The reliance on digital manufacturing by industry has grown as high performance computing technology evolves. Recognizing the far reaching implications of this technology on research, several government programs in the 1980's and 1990's promoted the growth of high performance computing. Today, programs such as XSEDE promote the use of high performance computing to conduct research in multiple fields such as engineering by supporting scholars and researchers in using these computational resources [3].

This proliferation of computational capabilities has generated a growing need in manufacturing industries to implement digital technologies to produce desirable products and bring them to market quickly. CAE allows engineers to use these computational resources to reduce or even eliminate the need for expensive physical prototypes by digitally analyzing the products and

systems to be manufactured [1]. Although the computational resources are available, developing engineers who are capable of using these resources effectively remains a challenge. Universities have incorporated introductory courses in CAE at the undergraduate level; however, these are often senior technical electives, and this limited exposure does not afford students the opportunity to become proficient at using these tools [4].

This paper explores the need for workforce development for engineers interested in implementing Computer Aided Engineering (CAE) tools. Characteristics of the adult learners are discussed followed by a presentation of the transfer problem in professional development. A theoretical framework to understand training transfer is then presented. A Certification in Practice under development at the Ohio State University is described with specific course design elements discussed which address the problematic issue of transfer for adult learners when considering professional development programs.

Characteristics of the Adult Learner

The notion that adults learn differently than children or adolescents is not new. The term andragogy was first coined by Alexander Kapp in 1833, and the leading scholar in the field, Malcolm Knowles, published his first article using the term in 1968 [5]. Since the target participants of a professional development program are adults, in order to best serve these learners, it is important to first gain an understanding of their fundamental characteristics. Table 1 presents a comparison of assumptions associated with pedagogy and andragogy [6].

Table 1: A comparison of assumptions of pedagogy and andragogy.

Regarding	Pedagogy	Andragogy	Notes
Concept of the learner	Dependent	Self-Directed	Generally, adults have a deep psychological need to be self-directed
Role of learners' experience	Little to none	Highly developed	Primary techniques for adults are experiential (labs, discussions, etc.) as opposed to transmittal (lectures, presentations)
Readiness to learn	Learn what society / the school dictates	Learn in order to cope more satisfyingly with real-life tasks/problems	Teaching vs helping to learn. Adult learning programs need to be organized around life- application categories
Orientation to learning	Subject-centered: acquiring content	Performance-centered: Developing increased competencies to achieve full potential in life	Adult learning experiences should be organized around competency-development

Adults enter a learning activity with well-established preconceptions. Since many of their previous learning experiences were based upon a pedagogical model, adults can become passive, uncomfortable, and potentially defensive. They are faced with the uncomfortable misconception that learners are dependent, and in order to participate in a learning activity, they must assume a dependent role [6]. This defensive stance can be exacerbated when the learners are faced with unfamiliar technology such as a distance education learning environment [7], [8]. Since adults are self-directed, this misconception must be overcome by treating the adults with respect by environmental considerations such as comfortable and adult-appropriate learning spaces, as well

as behavioral considerations such as the instructor treating the learners as partners rather than dependent learners [6]. An active role in planning the learning experience and a critical evaluation of what they need to learn also enables the learners to exercise their strength as self-directed learners [6], [8], [9]. Designing a project which is appropriate for the concepts presented to the learners is an example of a course design element which empowers the adults to be active participants in the course.

Adult learners derive their self-identity largely from their great depth of experience [6], [8], [9]. Because of this pre-existing knowledge, the participants learn from each other and have a richer foundation of experience to which to relate new experiences [6], [8]–[12]. In contrast, adults can also be less open minded due to fixed habits and an unwillingness to change. A constructivist approach enables the learners to be in control of their own learning, takes advantage of prior knowledge, and aims for deep processing of information [11]. This approach can also enable adults to overcome misconceptions and habits which may act as obstacles to their learning. They are able to control their own learning which generates more authentic learning [10], [11], [13].

For adults to engage in a learning environment, they need much more than a program dictating what they need to learn; the learners themselves must have a learning need that they want to address using a pragmatic approach [6], [9]. They want to increase current competencies, or branch out into new technical areas which can build on their current areas of expertise. They are ready to learn. A professional development program requires that certain standards must be met, but the participants require flexibility and options that fit the specific needs that they define as necessary to achieve their goals. This leads directly to the idea that adults' orientation to learning is performance-centered. Their goal in undertaking this effort is to increase competencies with the intention to apply this new knowledge immediately [6], [9].

The aim of the Ohio State University's Certificate Program in CAE is to integrate theoretical concepts with practical workplace application. Theory is presented alongside practice in order to relate them in an interactive manner [12]. By presenting theory alongside practice, adult learners are able to connect more abstract concepts to practical applications they face in their daily work routines.

The Transfer Problem in Professional Development

Human capital theory based in economics explains that education and training at all levels of the workforce drive productivity by supporting scientific and technical advances in society [14]. Industry invests several billion dollars in training each year and recognizes that today's knowledge driven economy requires this significant investment in order to succeed in a technologically driven economy [15], [16]. However, when considering an educational program designed to operate within the work environment, the issue of transfer must be addressed. Transfer is the degree to which participants successfully apply the knowledge, skills, and abilities gained during training to the job [17]. Figure 1 illustrates a model of the transfer process first presented by Baldwin and Ford [17] and updated in 2011 by Grossman and Salas [18].

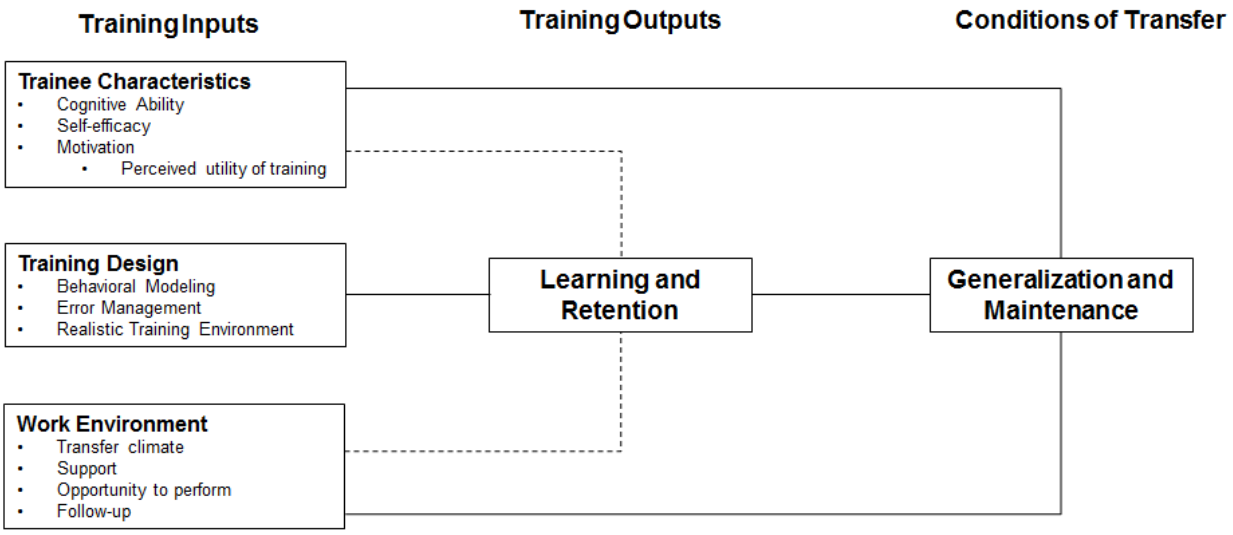

Figure 1: A model of the transfer process presented by Grossman and Salas [18].

Although industry invests heavily in training, research in this area indicates that training often does not result in the desired changed behaviors [19], [20]. The desired goal for training engineers in CAE is the widespread adoption of these tools in already established workflows. Due to the struggles associated with the generalization of knowledge acquired in a training activity, there is significant research regarding the transfer of training [17], [20]–[23]. Using this framework, a Certification in Practice of CAE is a program currently under development at the Ohio State University to support the teaching and learning of CAE for working engineers.

Designing to Enable Transfer

Although the issue of transfer is highly complex and is not limited to the inputs detailed in Figure 1, these inputs have been shown to be strongly correlated to positive transfer and therefore are being used to guide the development of this certificate program [18], [22], [23]. The program leverages current graduate course content which is repackaged to address significant barriers present to working engineers interested in graduate education. These barriers include the time investment required, travel, cost, as well as emotional barriers which many adults experience when contemplating a return to school [24]. Addressing these barriers is discussed using the lens of the transfer framework shown in Figure 1.

Trainee Characteristics

Since the program is based on graduate level coursework, it will be clearly communicated that either a bachelor's degree in engineering or a similar STEM field is required to successfully participate in this course. Individuals who would likely benefit from this program include product development engineers who have no previous CAE experience and are interested in gaining knowledge, skills, and abilities to use these tools to validate products virtually. Also, engineers who have expertise in one type of tool may be interested in gaining experience with a different CAE tool as coupled simulations become more feasible with expanding computing power. An example of a coupled simulation would be a fluid-structure interaction analysis which

would require knowledge of both structural modeling using the finite element method as well as fluid modeling using computational fluid dynamics.

Self-efficacy tends to be lower among adults learners when compared to traditional students due to feelings of being unprepared in academic settings [24], [25]. Including design elements which value adults' experiences as working engineers will encourage students to make connections between their roles as learners and engineers. A goal setting exercise is included at the beginning of the course to give students the opportunity to state their own goals for the course. Students will reflect on why they have chosen to participate in this class, and clarify what they expect to gain from these efforts so that they target their learning efforts to accomplish these goals. In addition, this type of activity encourages students to make connections between the class and their prior knowledge. Relating class activities with this prior knowledge will facilitate learning and retention [26]. Presenting this prior knowledge as an asset rather than a hindrance will support the adult learners' beliefs that they will succeed in this course and accomplish their goals for this learning experience.

Motivation is a complex topic which will only briefly be touched upon in this discussion. For adult learners in the workplace, two components of motivation which are of particular interest are perceived usefulness of the training, and the perceived ability to succeed at the training [27]. Perceived usefulness of the training is of particular interest for adult learners because they are pragmatic learners [6], [9]. This course includes a project which requires students to propose, build, and experiment with a model using the course concepts. Students are encouraged to look for project ideas from their own work environment with guidelines provided on the scope of the project such as type of solver and the number of components.

Projects and problem sets are graded iteratively to increase the feelings of success for the learners. As this is a not-for-credit course, grading is primarily a communication tool between the instructor and student. Feedback is provided throughout the course, and weekly assignments can be resubmitted so that students can improve their work and calibrate their learning. This grading approach generates a feedback mechanism which encourages students to monitor their learning [26]. As adults value their ability to be self-directed, iterative grading plays to this strength of the adult learner which, in turn, supports their feelings of motivation.

Care was taken to be respectful of the demands on the adult learners' schedule when designing this program. Adults' schedules are difficult to manage with both personal and professional demands, and often, adults do not feel that they can succeed in a program because of the demands on their time [25]. This certification course is designed to be completed within one academic year which will allow for more in-depth coverage than corporate training classes which typically last from a few hours to one week. Each certification will consist of four courses offered over two semesters as illustrated in Figure 2. A minimum of four courses must be taken to earn the certificate, but individuals are free to take stand-alone courses without earning a certificate. The weekly time commitment for individuals is restricted to an expectation of six hours weekly to complete the course requirements. This weekly time devoted to education and training is 15% of a 40 hour work week, and can be reasonably accommodated by both employee and employer with little impact to short-term productivity while engaging in training. Since adults continue with work and personal commitments while engaging in training, designing

programs to accommodate their schedules will support adult learners [24], [25]. This goes directly to their motivation to engage with a program such as this since they can readily see themselves successfully completing this program while maintaining their other work and life commitments [27], [28].

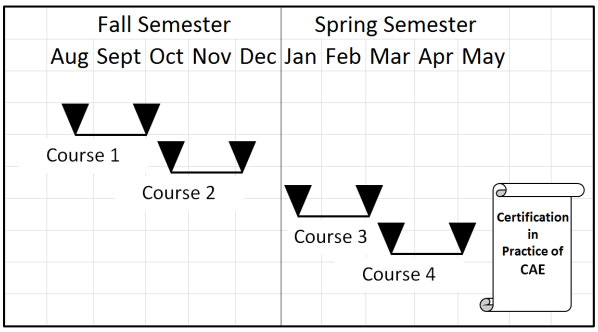

Figure 2: Proposed schedule for Certification in Practice in CAE at the Ohio State University

The cost for the entire program also reflects this streamlined content and falls below the $5250 limit for yearly tax-exempt tuition benefits received from employers [29]. Although some individuals will have employer support for participation, it is reasonable to predict that there will be those that wish to participate in this program without tuition support. Although not comparable to a full graduate program, this certification program will provide a stepping stone for individuals interested in developing knowledge, skills, and abilities with CAE tools which are considered highly desirable in today's modern engineering workplace [4], [30], [31].

Training Design

Extensive work has been done in understanding how the training design will influence transfer [32]–[34]. Several methods that are based in learning principles are available to training designers, and only a few are mentioned here which have shown strong correlation to transfer [18]. Behavior modeling is rooted in Bandura's social learning theory [35] and is an instructional design which (a) describes a well-defined set of skills, (b) provides models which demonstrate the effectives of these skills, (c) opportunities to practice skills, and (d) provides feedback to trainees as they practice [33]. Error management training (EMT) recognizes that errors are inevitable, and that they provide useful feedback while learning [32]. EMT does not seek to minimize errors such as more procedural approaches. Providing a problem statement and allowing the trainees to explore the problem with structured guidance will allow trainees to reflect on and manage errors. The trainers can then provide error management instruction to facilitate deeper learning which will contribute to the transfer of the knowledge to the work environment [18], [32], [36]. In this program, errors are not explicitly encouraged as defined by EMT, however, errors are tolerated and it is emphasized that recognizing errors is a key skill in the use of these tools.

Many organizations have adopted on-the-job (OTJ) training formats in order to provide realistic training environments. These programs keep trainees in the physical and social environment where the learned material will be applied [37]. This certification program is offered in a fully online, asynchronous format to situate the learners in the work environment and keep them "on

the job". Many instructional techniques such as problem-based learning simulate work problems to generate authentic learning environments for students in the classroom [36]. Situating the learners in their own work environments by using online learning technology makes it possible for this program to use the authentic work environment for the learning. The online learning format also alleviates travel barriers that working adults often need to manage. However, many of these adults may be novices to online learning and need support in how to function successfully as an online students. An introductory welcome module which includes resources and strategies for learning online is provided in the course. In addition, weekly assigned tasks encourage weekly participation throughout the course. Finally, weekly discussion posts which allow students to interact with each other discussing challenges in the course is a required element as it has been shown that generating a supportive social presence in any classroom, including the online space, supports learning [26], [38].

Work Environment

Once trainees have completed the training, the environment in which they need to apply the training is critical to transfer the knowledge. Key elements which contribute to a positive transfer climate is prompting employees to use new skills and providing feedback when the new skills are applied [17], [18]. Support is needed from supervisors and peers to foster a positive and constructive environment by engaging in goal-setting meetings, providing targeted feedback, as well as providing mentoring [18], [37], [39]. Time is needed after training to use the new skills, as well as opportunities to perform is needed to facilitate transfer. This can be challenging as trainees often find themselves short on time because they typically do not give up prior job responsibilities after training [18], [22], [23]. Related to training design, providing follow-up from the training enables trainers to offer feedback so that trainees can reflect and calibrate on their performance in the time that has passed since the formal training program ended [17], [18]. Currently, this program does not formally offer mechanisms to engage with the students post training. However, it is the expectation that engaging with the students who are situated in the learning environment over an extended time period will provide support to students as they work to transfer what they are learning within the class to their work problems. This is an area for further development of the program.

Discussion and Future Research

In summary, course elements were selected in order to promote the positive transfer of training. Figure 3 maps the input parameters of the framework to the course design elements. This illustrates not only how each input parameter is addressed, but how a single course element can address several input parameters.

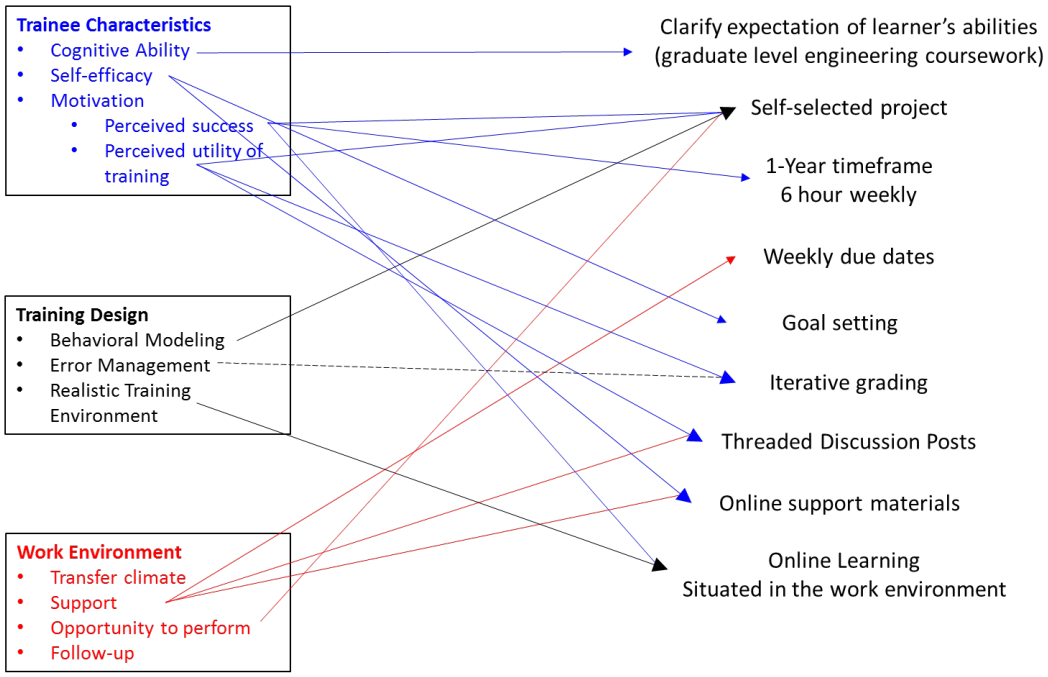

Figure 3: Transfer input parameters mapped to specific course design elements for CAE certification course

The evaluation plan relies upon a well-established survey tool which measures training transfer. The Learning Transfer System Inventory (LTSI) is an empirically derived self-report inventory instrument which is designed to assess perceptions related to training transfer of individuals undergoing workplace training [40]. The LTSI will be administered after the first class is completed in the sequence. We expect that there will be some students who decide not to continue on with the certificate program course sequence; therefore, administering the survey after the first class will maximize the sample numbers. For this particular study, the LTSI will be administered post-training in order to characterize the learners, the training design, and their work environment. An interview protocol will also be developed to follow up on this survey instrument, and interviews will be conducted 3-6 months after it has been administered by the research team. This will provide a richer data set to better understand the phenomenon of how engineers apply technical training to their work. In addition, conducting the interviews after several weeks will consider the effect of time passing on transfer rather than only measuring the intent to transfer. The program will be evaluated to see if participants are applying this knowledge to their work (i.e., transfer), and to understand what barriers or catalysts were present for this specific program which enabled or hindered the application of this training to the job. Currently, a more detailed evaluation design is a work-in-progress to be further developed in the summer of 2019 and implemented for the first cohort in the fall of 2019.

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