Enhancing Assessment of Experiential Learning in Engineering Education through Electronic Portfolios

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***Abstract*—Electronic portfolios (eportfolios) are proposed as an ideal mechanism to enhance experiential learning in undergraduate internships. Eportfolios can enhance instructors' ability to assess student learning outcomes and the ability of industrial mentors to supervise and direct interns. Further, eportfolios, through student reflection and direct assessment of activities, can help programs meet the challenges of program accreditation. In particular, we show the use of an assessment model for difficult-to-assess ABET outcomes.**

***Index Terms*—Eporfolios, internship, experiential learning, assessment, ABET**

I. Introduction

A. Experiential learning and assessment challenges

According to Kolb, et al., learning as defined by experiential learning theory is the "process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience."[1] Kolb describes experiential learning as a holistic process – joining the traditional concept of cognition with broader issues of thinking, feeling, perceiving and behaving. [2] In this work, the Kolbs explain the need to consider the learning space, consisting of both the student and their environment, in the assessment of learning from experiences. The learning space in which experiential learning occurs is broader than just the physical space, and includes the life experience of the learner outside the course or the classroom, and in fact outside the specific internship as well. Learning is enhanced when the context is understood, and our assessment should take into account a context which includes how a learning experience is connected to (encouraged or inhibited by, as well as supported by) the other aspects of the student's life and experiences.

The difficulty lies in understanding how the student experiences learning within this broad conceptual space. How do they connect learning in a course, a curriculum, or a research or internship experience with their other activities? How do they see how the interconnection amongst formal curriculum and experiential learning activities influences their ability to learn and their method of learning? How do they see their personal philosophy and their life goals developing as a result of their learning activities? To assess student learning gains as accurately and completely as possible, it is critical that educators build and use tools which can reach into this learning space, and provide data which can be evaluated. Electronic portfolios are proposed as an ideal tool for this purpose, one which is especially valuable for the assessment of learning gains in STEM education.

At one time, engineers learned their trade primarily through a process of apprenticeship. The student-master tradesman/artisan relationship allowed for an in-depth, real time observation of student learning and accomplishment, and provided a high level of mentorship and direction. With the growth of engineering, technology, manufacturing (and many other areas) with industrialization, urbanization, modern warfare, and needs of large populations, academic programs were designed to rapidly provide engineers in large numbers. Unfortunately, this reduced the opportunity for direct observation and personalized directed learning. Programs and schools responded with processes for accreditation, best-practices in curriculum design, and development of independent learning processes within the contact of structured curricula – primarily internships and research experiences. While these have clearly helped in complementing classroom based instruction, they have presented particular challenges to assessment and evaluation.

B. Electronic portfolios in engineering education

Multiple studies over the past decade have shown strong evidence that portfolios, and by extension, electronic portofolios (eportfolios), benefit student learning and acquisition of skills to enhance student success in STEM fields.[3,4,5] In an ASEE article, Knott, *et al.* offer a simple, concise definition: "A portfolio is a purposeful collection of artifacts to demonstrate effort, progress and achievement. Within an educational setting a portfolio can be prepared in the context of a course, a program, or an institution; the author of the portfolio can be the student, a faculty member, an administrator, or an organization; and the purpose of the portfolio may be developmental, evaluative, and/or representative. With the ever increasing use and advancement of technology, the electronic portfolio (ePortfolio) is emerging as a viable option to the traditional paper portfolio." [6]

Engineering students must develop a systematic, ordered approach to the gathering of data and solving of problems. As the student transitions into the workforce, she must continually learn and master new applications and materials, advancement in design and technologies, and societal complexities. The

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lifelong development, organization, and application of creative and critical thinking skills are vital to the success of an engineer. The goal of the engineering educator is to help students strengthen these abilities and guide them through the continuous processes of inquiry. Inquiry-Based Learning involves questioning, investigating (analyzing data), creating (synthesizing data into information), communicating (discussion and presentation), and reflecting on the knowledge gained. Reflecting on the evidence and conclusion produces more questions and the cycle of learning and discovery continues. Evidence-based reflective thought connects the inquiry cycle processes and serves as the catalyst to move to the next level of learning and discovery.

In particular is it very important that eportfolios build the inquiry-based and life-long learning skills of students. Through reflection, a primary component of portfolio-based learning, students express the skills which they require in order to become life-long learners. This is especially important for the success of students engaged in undergraduate engineering programs, as per the learning outcomes required in engineering and technology programs for accreditation by ABET [7]: " a recognition of the needs for and an ability to engage in lifelong learning." It is very difficult to devise assessment schemes which demonstrate attainment of this outcome – hence we have another valuable use for electronic portfolios in undergraduate engineering programs. Likewise, experiential learning can provide methods for assessment of several other ABET outcomes, including (d) the ability to function on multidisciplinary teams, (f) an understanding of professional and ethical responsibility, and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Even in the case of ABET outcome (a) "an ability to apply knowledge of mathematics, science, and engineering," experiential learning may provide one of the very few opportunities to evaluate how well a student can synthesize knowledge from coursework and apply that knowledge in to a new situation of set of problems.

Therefore using eportfolios in which students summarize their experiential learning and activities can provide a powerful tool for assessment of engineering programs. The eportfolio process itself, which consists of collecting, selecting, reflecting, and connecting evidence of learning, provides an organized digital thumbprint and timeline of knowing, doing, knowing how you know, and proceeding to the next level of inquiry. It allows the owner to synthesize learning, build knowledge, demonstrate learning connections, and project evidence of professional skills and abilities over a lifetime.[8] Using this for evaluation of attainment of ABET outcomes allows faculty coordinators to better understand how a student can integrate knowledge, use their skills in real-world situations and continue to develop those skills in a professional manner.

C. Evaluation of integrative learning

Integrative learning is a key skill for students to succeed in both life-long learning and in building self-identity as STEM learners and self-efficacy. In the AACU Integrative Learning Value Rubric, integrative learning is defined as an understanding and a disposition that a student builds across the curriculum, from making simple connections among ideas and experiences to synthesizing and transferring learning to new, complex situations within and beyond the campus.[9] A model for assessment of integrative learning, the Integrative Knowledge Portfolio Process Model (IKPP), has been developed by Peet, et al., at the University of Michigan.[10] The IKPP guides students with integrating, connecting, and synthesizing their learning experiences by identifying six dimensions of integrative knowledge and learning:

1. Identify, demonstrate and adapt knowledge gained within/across different contexts (i.e., the ability to recognize the tacit and explicit knowledge gained in specific learning experiences and the capacity to adapt that knowledge to new situations);
2. Adapt to differences in order to create solutions (i.e., the ability to identify and adapt to different people, situations, etc., while working with others to create positive change);
3. Understand and direct oneself as a learner (i.e., the ability to identify one's prior knowledge, recognize one's strengths and gaps as a learner, and know how one is motivated to learn);
4. Become a reflexive, accountable and relational learner (i.e., the ability to reflect on one's practices and clarify expectations within oneself while also seeking feedback from others);
5. Identify and discern one's own and others' perspectives (i.e., the ability to recognize the limitations of one's perspective and seek out and value the perspectives of others);
6. Develop a professional digital identity (i.e., the ability to imagine how one will use current knowledge and skills in future roles and how to create an intentional digital identity).

The IKPP Learning Model depicts conscious and unconscious learning as lifelong and life-wide experiences. In her research, Peet demonstrates that in order to truly integrate their learning, students must first learn how to identify and demonstrate the tacit knowledge (the unconscious and informal ways of knowing people develop from informal learning experiences) they have gained from previous experiences, and connect it to the explicit knowledge (the formal concepts, ideas and methods learned through formal education) they develop in their academic courses.

II. DESIGN OF EPORTFOLIOS

A. Design of a template for internship eportfolios

Our goal has been to work with students, faculty and industry to develop an electronic portfolio template and process which benefits all stakeholders. Students collect their experiences, reflect on their learning, and relate their internship to other academic and life pursuits, showing how it has expanded and enhanced their educational experience and provided key skills valuable for life-long learning. Faculty can use the portfolios to evaluate and assess the student experience, provide feedback, and relate internship learning objectives to institutional and programmatic learning objectives, relevant to accreditation. Industry and potential mentors are able to use the portfolios to track and advise students, monitor progress, and identify interns who may be offered permanent positions.

Integrative Learning ePortfolios (such as the ones created by our interns) are used to facilitate and organize the inquiry process as students make meaning of the knowledge and skills gained and connect (apply) them to other life experiences. The eportfolio serves as a learning space to scaffold and apply knowledge gained through inquiry and scientific, reflective thought. It also helps faculty to track and guide the students as they develop, organize, and apply their creative and critical skills. The Integrative ePortfolio Learning Process (**Collect** - gather and analyze data, **Select** - synthesize data into relevant information, **Reflect**, **Connect**, and **Project** to the next level of learning) provides an organized digital thumbprint and timeline of knowing, doing, knowing how you know, connecting what know, and proceeding on to another level of inquiry and knowledge. It allows the student to analyze and synthesize the learning experience, apply the learning to build knowledge, demonstrate learning connections, and project evidence of academic and professional skills and abilities over a lifetime. It allows the faculty to guide the student and authentically access the learning outcomes.

At the same time, the Integrative ePortfolio Learning Process helps the student to develop self-determined, lifelong learning skills. The eportfolios are owned by the students and provides an organized space for self-assessment. As students document and reflect on curricular, co-curricular, internship and job experiences, and service activities within the integrative eportfolio, they develop a sense of autonomy, self-relatedness, and self-efficacy as they extend their learning experiences beyond the bounds of the classroom. The learned concepts in the classroom, easily and confidently, can be mapped to the internship experience and into the workforce.

B. Creating an assessment rubric and process

The grading rubric for the eportfolios is provided as part of the template used by students enrolled in ESM 488, the internship course in the Engineering Science curriculum at Stony Brook University. The rubric focuses on evidence presented in five categories: (1) demonstrate a professional attitude and work ethic; (2) excel at serving on multidisciplinary teams; (3) excel at communicating clearly and effectively; (4) excel at using the techniques, skills and technologies necessary for engineering; and (5) demonstrate independence and self-reliance (self-efficacy) in identifying information needed to complete tasks, in locating that information and in applying it to the task at hand. Tasks specific to a particular internship (collecting data, design, solving engineering problems, etc.) are also integrated into the rubric. Overall, the rubric and our assessment plan focuses on four categories: **effective teamwork** (cited highest as a skill desired in job applicants by the National Association of Colleges and Employers, 2012); **professionalism** (including ethics); the importance of being a **life-long learner**; and **integrative learning** (including applying science and engineering course-based knowledge to real-world situations).

In our design of an assessment process, we also leverage and adapt a number of best-practices. One is the IKPP Learning Model described above. Another is the AACU Foundations and Skills for Lifelong Integrative Learning Value rubric, which categorizes the objectives of the integrative learning process as: (1) Connections to Experience - Connects relevant experience and academic knowledge; (2) Connections to Discipline - Sees (makes) connections across disciplines, perspectives; (3) Transfer - Adapts and applies skills, abilities, theories, or methodologies gained in one situation to new situations; (4) Integrated Communication; and (5) Reflection and Self-Assessment - Demonstrates a developing sense of self as a learner, building on prior experiences to respond to new and challenging contexts. [11]

In summary, we have developed an assessment methodology which leverages the dimensions of learning listed above and matches these with the skills and experiences relevant to key ABET learning outcomes in engineering knowledge and skills (outcome a), multi-disciplinary teams (d), life-long learning (i), and professionalism (k). In addition, we require each intern's supervisor or mentor to rate the student's skills or abilities in each area of the ABET learning outcomes they find relevant to the particular internship experience.

The results of these assessments are summarized in tables 1 and 2 below. Table 1 provides examples of student language, culled from their reflections in their eportfolios, selected to reflect student gains. There are many more examples of such reflections in the eportfolios, and a faculty coordinator evaluating the eportfolios can use examples and a rubric to determine whether or not a student demonstrates that they have achieved particular learning gains. This can be done through a qualitative process, where by a student demonstrates, through a combination of direct evidence and reflection, that they have a demonstrated skill (for example, to extend classroom knowledge to new examples, or to participate in multi-disciplinary team meetings) or have gained an appreciation for extending their learning beyond curricular activities or have enhanced their self-identity as a STEM learner (and hopefully as a developing professional engineer). Our rubric (not shown) is somewhat subjective of course, and depends heavily on the expert opinion of the evaluating faculty. This is a sufficient methodology, as such expert opinion has been considered valid in rank-ordering methods and other forms of academic assessment of student reflections and self-assessment language in portfolios – for example, in the case of professional and medical education. [12,13]

Table 2 summarizes the result of employer feedback generated through a survey which is included within the students' eportfolio. By having their supervisors fill out the survey, not only do faculty have another tool for assessment but also the student is encouraged to explore the experiential learning nature of the internship with their mentor. The validity of the survey of course depends on employers/mentors interpretation of the questions. To date, only one employer expressed any difficulty in interpreting the questions (based on the nature of the experience).

III. Results

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Student (gender, year)	Identify, demonstrate and adapt knowledge gained within/across different contexts (ABET outcome a)	Self-identification as a life-long learner in STEM (ABET outcome i)	Ability to reflect on learning process	Ability to function on multi-disciplinary teams (ABET outcome d)	Develop a professional digital identity; ability to conduct self professionally and ethically (ABET f)
3rd year, female	"my … skills improved tremendously and I have gained more confidence in completing projects. I have **learned it really isn't about all the classes you have taken** and have seen how engineers balance multiple projects at once all at different stages of completion."	"My summer internship was only for about a month, but even in that short of a time I learned a lot and worked with some really amazing people! … Though my time there was on the shorter side, I feel like I have **a better grasp of what to expect in the real world**"	"I have gotten more familiar with AutoCAD Civil 3D. I was extremely nervous at first, as this seemed like a major step-up from my classes …. I have to admit that I was lost and **always needed to ask for help to be walked through the use of most tools I needed to use, but that my confidence in using the software did grow** …."	**Descriptions of collaborative tasks** with other employees at company.	Internship well integrated with eportfolio sections on senior design, undergraduate courses taken, community service, clubs and activities
3rd year, male	"[An internship] not only gives you an idea of what you are going to do, but also a chance to use skills you have learned from school. **For me, learning from school was learning to find the pieces of a huge puzzle and working for [the company] was a way to combine the pieces in the right place**."	"Studying in school is a great chance to grasp the basic knowledge about engineering. But working in an engineering field is a totally different experience… I am expected to graduate at 2015 and **I can't wait to go out to the field and have a great future**."	"**Being an engineer was something like having another eye that normally people do not have.** You need to search for yourself to see what you can fix and what you can improve… **engineers need to be creative and think from all different angles**. That is why they have meetings to share their own ideas and think from a different perspective."	Generally people say engineers need to "think outside of the box" and that is exactly what I learned.. That is why they **often have meetings to share their own ideas and think from a different perspective**"	Internship section combined with specific course sections, as well as recommendations, and a video clip of a musical performance and connection to student's linkedin page.
4th year, female	"… overall I learned new skills, abilities, and worked with industry standard equipment. This internship surpassed my expectations which was to **gain real world engineering knowledge** in an industry setting."	"Each day that I worked at [the company] I learned more and more new skills and engineering related knowledge, and I feel that this internship, turned into summer job, helped teach and **mold me into a better future engineer**."	"Throughout my daily work I **learned and refined many skills** and I had the chance to **see how other engineers perform their daily tasks**…."	"In a small firm,. no one person has a single task in a given day. **They work on multiple tasks and managing multiple projects."**	Extensive eportfolio, integrating two internships with courses, clubs and professional societies, volunteer work, and even high school robotics contests.
4th year, male	"What I have learned has also **allowed me to apply my learned skills and**	"This experience… helped me organize my academic work and **goals towards**	"I gained the ability to **quickly analyze a situation and come up with a possible solution** with	"The path to ones success is never easy and cannot be taken	Stand alone internship eportfolio, but very complete and

	abilities to other areas of my life." "Education is not limited to just the classroom or a specific course of study..."	**becoming an engineer** in the field of aviation." "Knowledge, experience, diversity and the pursuit for answers are the main cornerstones for someone's education **over the course of their life**"	little modification of the solution or task needed. Organization of the work process also was very important and I learned to **plan work out ahead of time** to minimize down time."	alone. **Team work**, trust, respect and loyalty along with education, hard work and perseverance are the key aspects to obtaining success."	professional. Includes bio, resume and links.
3rd year, female	"Working in an industrial setting helped me to **see the direct applications of scientific information compared to my previous experience** largely in an academic setting."	"I plan to pursue a career in the biomedical engineering field in the future. My professional aim is to **further advance my studies** in engineering/science by pursuing a PhD. "	"…my supervisor was able to provide me with constructive criticism that helped improve my knowledge … This internship **allowed my intellectual ability to thrive** and … understand the collaborations between scientists and engineers."	"The entire process **required collaborations** between different departments which relied on each other…."	Stand-alone internship eportfolio, includes resume, Prezi presentation on experience gained in internship.
3rd year, male	"…This experience allowed me to see that the engineering field is **way more than just calculus and physics and being isolated**. … It has shown me that there is a lot more that goes into engineering then I had previously realized."	" [This internship] has shown me that for a career path I really do enjoy the engineering field… Two of my biggest goals are to **always keep learning** and to leave a lasting impression. The drive to keep learning is something that I will carry with me throughout my life…."	"From this internship I was able to see … **the amount of thinking that goes into every statement** before it is made. Each move …is carefully calculated as far as what all possible outcomes could potentially be, and it is in this that I noticed the biggest difference between professionals and students."	"It has shown me the power and significance of **working as a team** and how being able to communicate with your team is crucial to a successful work environment."	Stand-alone, well-designed internship eportfolio, includes bio and resume. "From this internship I was able to see how **professional engineers** carry themselves and go about their work…"
4th year, female	"**It was rewarding to be able to apply some of the knowledge I gained in school outside of the classroom**." "This internship taught me … how simple introductory classes that we took in college could become very applicable to the real world."	"Upon graduation, I will start my career as an engineer for a construction management company. I believe that a successful career is always driven by the person's **desire to continue learning**, which is why obtaining my MBA is one of my most valuable goals."	"…. I now know for sure that I would like to pursue a career in construction management **I also know that I have much more to learn** when dealing with contractors and putting together contracts... Despite everything I still have to learn, staff were always willing to take time to help me as well as explain new topics"	"As I observed the way co-workers effectively communicated, I realized the **importance of working as a team** and learning to accept and adapt to the personalities of others."	Stand-alone, well-designed internship eportfolio, includes bio, quotes and resume. "Aside from the technical skills I gained, I can also say that I grew as a professional."
4th year, male	"This experience gave me great insight because it included all engineering disciplines… This **gave me great insight to the business of engineering,** as	"This project actually **helped me decide which career path in the engineering field I would take**. When I started on this project, I was a mechanical engineering	"The people I worked for and with were very helpful to me and would show me the right way to complete all of my tasks. … **I learned a lot from them also, because I would sit in on**	"The biggest thing I gained from this experience is the **teamwork that goes into making the project a success**….	"There are many accomplishments I would like to be able to say I have achieved when I look back at my work at the end of my

	well as the day to day tasks of each individual discipline."	student …but when I was exposed to the environmental aspect, it interested me a great deal and I decided to pursue that career."	**meetings and take notes on the day to day operations...**."	This experience gave me great insight because it included all engineering disciplines..."	career. The first thing is that I want to **have had a positive effect on my coworkers and the community that I have worked in**."
3rd year, male	"One of the most important things I learned from my internship experience was **how real life constraints affect the overall design of the final project**. Many times in class we design a project theoretically however … not everything you imagine will work in reality."	" …The **value of education which is always continuing** is key to the success of the profession... The basic knowledge I gained will be the foundation for my continually growing career in the field of engineering"	"…I continually **learned new tools and methods to carry out the designs** I worked on. This helped to learn the more efficient ways to model a project and broadened my understanding of the software."	" Many times the internship activities were steps that contributed to the bigger picture of the project where the **other engineers relied on my task to move forward** with the design on their project.."	Stand-alone internship eportfolio, with resume and bio. "Engineers must perform their work in an **ethical way that promotes safety to the public** in which it serves."
3rd year, male	"This experience showed me what engineers do on a daily basis. Prior to this, I had only a vague idea based on things we had done in class. …**I had to apply a lot of what I learned in school to the job and had to learn even more**."	"This experience has **shown me that I want to work as an engineering manager**."	"Furthermore, **I became significantly more self sufficient, researching and learning things for myself rather than asking for help**."	"Over the course of my internship …, I learned about the Six Sigma program **and how to better optimize group projects**.	"Having worked with several different engineers over the course of my internship, i learned a great deal about the skills and abilities they implement each day, including their great work ethic."

Table 1:Examples of eportfolio statements and materials which provide evidence of integrative learning as related to ABET outcomes

ABET LEARNING OUTCOMES	EMPLOYER RESPONSE ON HOW WELL STUDENT MET LEARNING OBJECTIVES (AVERAGE) (FROM 1 – VERY WELL TO 5 –NOT WELL)
(a) an ability to apply knowledge of mathematics, science, and engineering	1.5 (0.16)
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	1.31 (0.13)
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	1.92 (0.24)
(d) an ability to function on multidisciplinary teams	1.25 (0.11)
(e) an ability to identify, formulate, and solve engineering problems	1.63 (0.16)
(f) an understanding of professional and ethical responsibility	1.63 (0.16)
(g) an ability to communicate effectively	1.56 (0.16)
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	1.5 (0.17)
(i) a recognition of the need for, and an ability to engage in life-long learning	1.25 (0.11)
(j) a knowledge of contemporary issues	1.5 (0.13)
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	1.88 (0.20)

Table 2: Results of employer/supervisor surveys. Results show average response, and the standard error of the mean (standard deviation/square root of number of responses).

IV. CONCLUSIONS

Clearly, the results of assessment indicate that students demonstrate considerable learning gains in integrated learning and, by extension, in ABET learning outcomes. This achievement is reflected in the results of employer/supervisor/mentor surveys which directly address these areas. In particular, employers found that interns ranked best in ability to function on multidisciplinary teams and in their recognition for and an ability to engage in life-long learning. Indeed, students' self identification as life-long learners as a result of their experiential learning internships indicates that a key goal of engineering education has been attained, and is reflected in their eportfolio reflections.

Employers were not universally satisfied with students' design abilities, as well as the depth of their understanding of the tools and techniques of modern engineering practice (areas which received the lowest scores). Yet these are also the areas which students most often cited as challenges to their own learning. Engineering and technology (and indeed STEM areas in general) pose significant challenges for students due to the constantly evolving nature of the field – new materials, software, testing and modeling tools, manufacturing methods, and communications and presentation media provide both frustrations (for student and employer alike) and opportunities for growth. Through their eportfolios, it is clear that students recognize the need to improve learning in these areas, and their demonstrated growth in metacognition of learning and in self-efficacy (indicated by evidence and reflections) can only better serve to help them achieve these necessary learning gains. Some additional challenges in less technical areas also still exist – for example in helping students to present a professional identity and understand their professional responsibilities. We will respond in this area through additional student preparation for internships (using on-line resources and by interacting more with students through their eportfolios).

Overall, the results demonstrate that electronic portfolios, along with a well-designed rubric and assessment methods based on best practices, meet the need of facilitating the ability of faculty to "measure the immeasurable" in regard to ABET learning outcomes in undergraduate engineering programs.

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