Formalizing Experiential Learning Requirements in an Existing Interdisciplinary Engineering Curriculum

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In education, experiential learning has become a best practice, high-impact strategy, because engaging with real life problems heightens students' interest, teaches them career-related skills, and enables them to become more self-aware/mature independent thinkers. While many students engage in experiential learning activities voluntarily, some schools have formalized a credited version as an elective to ensure the learning includes the reflective and conceptual components, as verified by a deliverable outcome. A few schools such as Messiah College have also gone a step further to require an approved experiential learning activity of all students, including engineering majors, to enhance their career preparation and community engagement before graduation. Students matriculating to Messiah College as of 2015 may now opt to fulfill the Experiential Learning Initiative (ELI) by either credited internship, practicum, service learning, leadership, off campus program, or research. While pre-graduation professional preparation may be new for some liberal arts disciplines, engineering has encouraged an experiential approach for some time. Since 2007, the Engineering Department at our institution has required students to complete a multiyear "practicum" which functions as an on-campus credited internship with our Collaboratory for Strategic Partnerships and Applied Research. Junior and senior engineering students receive credit for such project work through a four-semester Engineering Project 1-4 sequence, coupled with a two-semester Engineering Seminar 1-2 sequence as the reflective component. What remains is to incorporate the new features of the ELI mandate. While many engineering students on their own already complete paid internships with off-campus companies before graduation, to avoid extra tuition expense and unneeded credits, few opt for an academically approved internship with its intentional reflective component. Thus, we have decided to embed the specific ELI requirements related to reflection and the deliverable into our existing on-campus required upper divisional project curriculum structure. In our Seminar 1 course, students write four pre-experience learning objectives in stipulated areas; during Seminar 2, they complete correlated post-experience reflective questions, and compose a deliverable. In between Seminar 1 and 2, students have one to three semesters of work experience in their Project 1-4 courses, to serve as the basis of their reflection. As an example of how engineering at our institution has implemented a new college-wide formalized experiential learning requirement, this paper details its incorporation into our existing curriculum, the nature of formative and reflective questions used, parameters of students' structured experience, expectations of the evaluative rubric used for assessment, specifications of the deliverable, and connection to the Kolb model. This paper also identifies and briefly describes a sample of the interdisciplinary projects from which our students choose to do their project experience, some local and others international in scope, providing a range of impactful experiences on which to reflect.

I. Introduction: Experiential Learning

A well-known psychological model developed by Kolb explains how experiences can result in effective learning.[1] Since then, experiential learning has risen to the status of an educational best practice, by providing motivational context, helping students acquire career-related skills, and shaping them into more mature independent thinkers. Several schools have adopted integrative studies programs to capitalize on the benefits of this strategy.[2] Messiah College, a Christian college of the liberal and applied arts and sciences in south central Pennsylvania, has recently launched a college-wide Experiential Learning Initiative (ELI) requiring all students who matriculated as of 2015 to complete an approved ELI activity before graduation.[3]

Within engineering education, the experiential learning strategy has also become increasingly popular; in many cases, engineers have pioneered the approach for other disciplines. Since 2007, the Engineering Department at Messiah College has been requiring students to complete a multiyear "practicum" that functions as an on-campus credited internship with the Collaboratory for Strategic Partnerships and Applied Research (http://www.messiah.edu/collaboratory). Elsewhere, recent papers in the literature have reported on studies in the wider engineering education community to improve the impact, integrate grand challenges, develop projects as best practice examples, identify strategic alliances, and accommodate global perspectives. [4-8]

More attention to formally implementing experiential learning in the curriculum with effective resources would facilitate and authenticate its adoption as a standard practice by other schools, enabling more students to enjoy the full-fledged benefits of improved preparation. Thus, as a contribution to practitioner knowledge, this paper describes how our program, which already supports a wide array of ongoing interdisciplinary engineering projects, satisfies the new campus-wide ELI graduation requirement; ELI features now being embedded into the existing curriculum structure enhance overall learning benefits by guiding students' reflection through personalized objectives to realized outcomes. Other schools in similar situations may be able to draw transferable lessons to their context, by adapting strategies we have employed.

At this stage, formalizing our engineering project curriculum as authentic experiential learning represents a work in progress involving a pilot group of five engineering students who must satisfy the new ELI requirements by spring 2017 to graduate on schedule. Results of this pilot group help test our plan, providing feedback to inform us what adjustments we may need to make, as we ramp up to the "full-on" implementation of 50+ students per year over the next two years. As available, this paper presents details of the ongoing pilot group results.

Having introduced the case for experiential learning with its move from popularity toward maturity in engineering education, and having described the purpose for this paper, the next section focuses on how and where we have embedded elements of the ELI mandate into our existing engineering curriculum.

II. Methods: Embedding ELI Requirements into Existing Engineering Curriculum

Previous papers have described elements of the credited engineering interdisciplinary multiyear project curriculum structure at our institution[9] and how students join teams by a competitive process to participate in ongoing project work.[10] As related background for this paper, Messiah College currently offers the B.S.E. degree, with six concentrations: biomedical, civil, computer, electrical, environmental and mechanical engineering. The nature of our client-based project applications determines what mix of engineering concentrations teams may need to be successful; certain project teams even "employ" students with majors outside of engineering to achieve their results. Non-credited students participate voluntarily through the Collaboratory, but team leaders recruit them by a similar competitive process. Thus, the interdisciplinary nature of project work includes engineering students who do credited work with others on teams across sub-disciplines; some of these students also work with others on teams across major disciplines.

Engineering students admitted to a concentration enter the upper-divisional tier of our program, including the required four-semester engineering project (P1-4) sequence (see Figure 1 below). While the Practicum label might apply, this project experience actually functions as an on-campus credited internship. Junior students earn one credit during their fall (P1) and spring (P2) semesters for team-oriented project work participation, while senior students earn two credits during fall (P3) and spring (P4). For their two credits, seniors should devote roughly twice the time as juniors, with the increased project responsibility and leadership at the senior level.

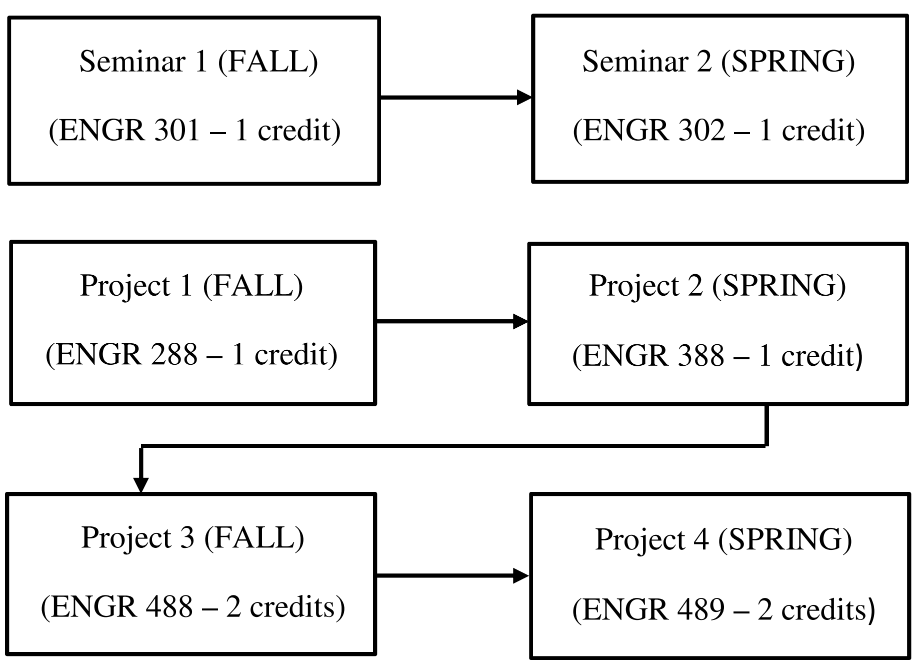

Figure 1. Existing Engineering Project and Seminar sequence courses offered concurrently during the corresponding fall and spring semesters at Messiah College, with credits as indicated.

Concurrent with the P1-4 sequence, engineering students in the upper divisional tier must enroll in the Seminar 1-2 sequence (Figure 1). Students may register for Seminar 1 (S1) during the fall semester and Seminar 2 (S2) during the spring semester of either their junior or senior year; each course has one class meeting a week for one academic credit. S1 serves as a pre-requisite for S2, so students must take them in that order. As our Seminar 1-2 sequence has already been providing students with supplemental philosophical and cultural background to the engineering discipline, and soft-skills with practical preparation to help them get started in their career, the advent of the ELI mandate at our school makes S1-2 an ideal place to embed the ELI elements.

Three signature elements of the ELI graduation requirement at Messiah College have been formulated to ensure authenticity, per the Kolb model, but also uniquely orient a student "…to outcomes related to enhanced career preparation and community engagement." The ELI signature elements are 1) learning objectives, 2) learning outcomes and 3) the ELI deliverable. Students are required to design their learning objectives at the beginning of the experience in four areas: a) personal, b) professional, c) academic and d) community engagement. Each of these areas includes an ELI common reflection question (see Table 1) which serves as a prompt, to guide formulation of learning objectives in the intended direction. Students personalize objectives in each category, based on their unique project application, role and individuality.

Table 1. ELI common reflection questions for each category of required learning objective.

Category	**ELI Common Reflection Question**
Personal	How do you expect to grow personally (e.g. in your self-awareness, your spirituality, and how you relate to others) through this experience?
Professional	Regardless of whether or not your ELI relates explicitly to your career goals, what specific skills do you plan to develop/enhance that would be transferable to your professional goals?
Academic	In what specific ways do you hope to grow as a student? How do you hope your ELI will connect to your major and classroom experiences?
Community Engagement	What do you hope to learn about the "bigger picture" of community (local or global) from your ELI?

ELI Activity in Seminar 1: Formulating Personalized Learning Objectives (ELI Proposal)

The S1 course schedules the Learning Objectives element of the ELI requirement (see Figure 2 below for timeline) as an individual assignment entitled ELI Proposal. The ELI Proposal assignment as devised consists of three parts: 1) a cover page, 2) project information, and 3) the individual ELI Learning Objectives. The cover page consists of the project title, date, student name and advisor name. Seminar students draw the project information from a project document required by P1-4 courses known as the "Project Charter", including a brief description (abstract) of the proposed or ongoing project, background to establish sufficient context for the project, and its goals including milestones and review dates.

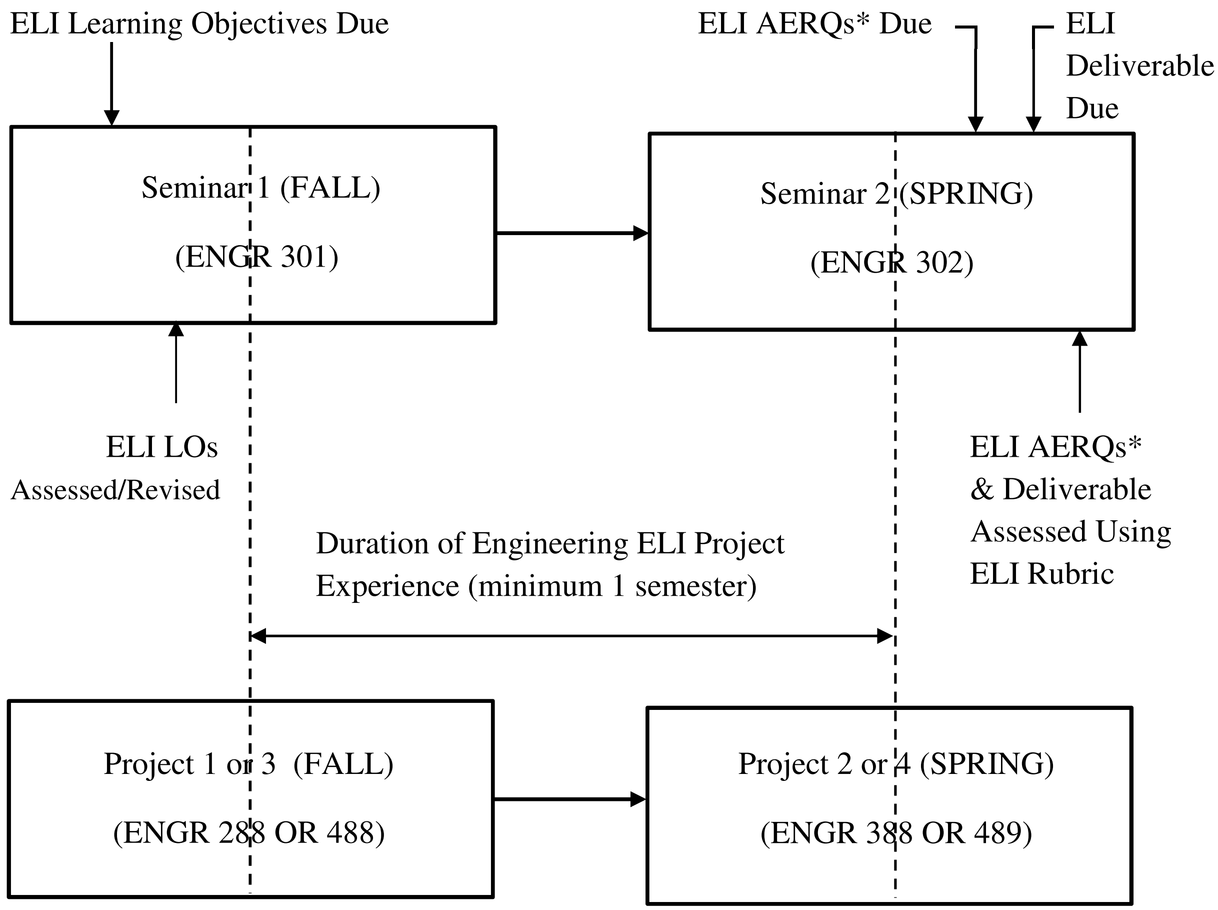

Figure 2. Timeline of ELI signature elements embedded into existing engineering curriculum, to ensure a minimum one-semester project experience across the P1-4 course sequence.
*AERQs ≡ Additional ELI Reflection Questions, and LOs ≡ Learning Objectives.

Assigning the ELI Proposal during the first half of the fall S1 semester and an ELI Learning Outcomes element during the second half of the spring S2 semester ensures that students concurrently enrolled in the P1-4 sequence have at least a one-semester equivalent (40 hours) experience of project work to reflect upon. Students who take S1 during the fall of their junior year, and S2 during the spring of their senior year would have closer to three full semesters of project experience (P1 through 4) between the writing their learning objectives, and identifying their learning outcomes. Though the three semesters of project work might be more ideal for students to reflect upon for ELI purposes, only a one-semester minimum is currently required.

ELI Activity in Engineering Project 1-4: Experiencing Client-based Project Work

While registered for S1, engineering students also concurrently enroll in either P1 as a junior, or P3 as a senior (as shown in Figure 2) to work with a team of students on a project approved by the Collaboratory. This project work experience by students involves teamwork with other students under the supervision of a faculty advisor and/or an external client representative. The location and mode of activity consist of either on-campus internship and/or off-campus site team implementation. Nature of the work entails documented planning, task definition & estimation, task completion, documented reporting, and oral review. Students document their plans by establishing or revising a Project Charter (updated at least annually) and formulating technical project objectives to satisfy our Minimum Viable Progress (MVP) requirements. Student teams define their own "to do" list by brainstorming necessary engineering tasks, delegating and scheduling them in logical order, and estimate how much time it will take to complete them. Each student spends at least two scheduled periods with their project team each week and often time outside of class as well toward completing their assigned tasks. Each student also reports on task completion through individual Project Records, while also contributing input to the single team Project Report submitted once each six to nine-week MVP period. Each designated MVP period culminates with an MVP meeting like a design review. At the MVP review, the student team makes an information presentation of its objectives and progress over the most recent six to nine-week period before a review panel including knowledge experts, the client and the project manager. After a period of discussion between the panel and the team, including questions, responses, and suggestions from the panel, panel members evaluate the team on its most recent progress and presentation, using a preset standard evaluation rubric designed for this purpose. More details on these project-work methods appears in a previous publication.[10]

ELI Activity in Seminar 2: Identifying the ELI Learning Outcomes and Creating the Deliverable

The S2 course schedules the assigned Learning Outcomes and the Deliverable elements of ELI, during the second half of the semester (see Figure 2 for timeline). To identify the ELI Learning Outcomes, students must answer in writing a set of eight Additional ELI Reflection Questions (AERQs—see Appendix A.1), a college-wide standard at our school. Responding to the AERQs facilitates student reflection on both their Learning Objectives previously formulated, and their engineering project experience since then, focusing attention on key aspects of personal growth, career-skill preparation, application of academic learning, and community engagement. The Learning Outcomes activity integrates with preparation students do to write a five to seven-page course paper articulating their vocational vision, defending their choices based on readings assigned during S2. Each student submits their personal responses to the AERQs for evaluation by the S2 instructor. The S2 instructor assesses AERQ responses using the college-wide "Assessment Rubric for All ELI Experiences" (Appendix). If approved, the student uses these AERQ responses, and their Outcomes Commentary (correlated with each Learning Objective), to compose their ELI Deliverable. The Deliverable consists of a 300 to 400-word summarized reflection uploaded either to a personal website, LinkedIn site, or other ePortfolio accessible for a prospective professional employer to read, with a link submitted to the S2 instructor for final evaluation. The S2 instructor then assesses the ELI Deliverable as the last item of the ELI rubric, to determine whether a student has satisfied the whole of their ELI requirement.

Having described how our existing engineering curriculum now incorporates the ELI requirements, the next section will present information about our pilot group of students, and the results available from them so far.

III. Results: Student Outcomes for Initial 2016/17 Pilot Group & Interdisciplinary Mix

The pilot group consists of five engineering students who matriculated to Messiah College as of Fall 2015 as transfers, and thus enrolled in our Seminar 1-2 sequence during the 2016/17 academic year as juniors or seniors. Table 2 below identifies and briefly describes the five different projects these students joined. All five of these students successfully completed writing their four individualized Learning Objectives in specified categories of personal, professional, academic and community engagement, as approved by Seminar 1 instructors during Fall 2016.

Table 2. Project Identification and Descriptions for the 2016/17 Engineering Pilot Group Sample

Student # & Project Title	Brief Project Description
1. AWDS	African Water Sanitation and Hygiene (WASH) group developing a hand washing station modified for easier access by those with disabilities
2. Breath of Life	Modify design of oxygen concentrators that will properly function in the humid climate of Zambia, to support patients with respiratory difficulties
3. WERCware	Develop assistive communication technology remotely delivering social coaching services to those with cognitive or behavioral disabilities
4. Mexico Bridge	Design bridge in Oaxaca to cross a flooded drainage ditch to a community center; refurbish a basketball court & regrade land to manage runoff
5. WFTW	Wheels for the World: creating practical/affordable mobility options for individuals unable to move independently in developing world locations

As of the date of this writing, three of the five pilot group students have submitted approved responses to their Additional ELI Reflection Questions (AERQs) in Seminar 2, during the Spring 2017 semester. Their last step is to complete the ELI Deliverable at the end of the semester. Final results of the ELI Rubric evaluation will be available for presentation at the conference.

Table 3 below indicates details of the interdisciplinary makeup for each project team represented by this pilot group. Details include the engineering concentrations and other majors (if any) pursued by each team member. Four out of five of these projects has interdisciplinary representation consisting of multiple engineering concentrations, while one of these teams also includes a student from another major, specifically Computer and Information Systems. This pilot group represents just a small sample of the overall number of projects in the Collaboratory.

Table 3. Number and Distribution of Students Among Engineering Concentrations and Other Majors. In certain cases, these numbers* include students with a double-concentration.

Project Title	# of Students on the Team	Engineering Concentrations Represented						Other Majors
		B.E.	Civ.E.	Comp. E.	E.E.	Env. E.	M.E.	
AWDS	4	--	2	--	--	--	2	--
Breath of Life	7	2	--	--	--	--	5	--
WERCware	6	--	--	4*	4*	--	--	1
Mexico Bridge	4	4	--	--	--	--	--	--
WFTW	6	2	1	--	--	--	3	--

Overall, the Collaboratory at Messiah College is currently sustaining over 36 ongoing projects, involving a total of 218 students, and 18 majors. Majors students pursue outside of engineering include Anthropology, Biochemistry, Business, Chinese, Computer & Information Systems, Computer Science, Digital Media, Education (Early Childhood, History of, Secondary, Special, Math & Science), English, Marketing, Politics, Public Relations, Social Work, Studio Art. Project teams have an average of six student members. The predominantly engineering teams (33 of 36) include an average of two different engineering concentrations; seven of the predominantly engineering teams include one non-engineering major among student members.

IV. Discussion

We incorporate the new Experiential Learning Initiative (ELI) requirement in our existing engineering curriculum differently than other departments do at our school. Our approach for engineering involves distributing the project experience across two or more credited courses, and responsibility for evaluating student reflection by faculty who are not necessarily project mentors. Despite the “moving parts” in this approach, we believe it will work successfully, due to accessibility of documentation our Project 1-4 sequence already provides, and the availability of project mentors for consultation by Seminar 1-2 faculty, when needed. Our experience with the pilot group suggests that to ensure quality, we need to 1) set strict enough deadlines for students submitting their Learning Objectives during Seminar 1, so they can reflect on at least one semester of project experience, and 2) build sufficient margin into scheduling ELI element assignments, to allow students time to resubmit revised work, if unacceptable on first draft.

Regarding the interdisciplinary makeup of project teams, a better balance of engineering concentrations might optimize the productivity of some. However, overall enrollment and student choice limit the number of students in each concentration, so that the “labor supply” during competitive recruitment may not match the demand. For example, the demand (identified project need) for engineering students with an electrical concentration typically exceeds the labor supply. Such imbalances expose students to realistic conditions in the marketplace.

V. Conclusions and Future Work

The strengths of experiential learning noted here have recently made it a popular strategy in education at large, and in engineering education specifically. However, a formalized plan should include guided and focused reflection on the experience, as per the Kolb model, culminated in a deliverable evaluated by faculty to ensure authenticity and effectiveness of the learning process. This paper has detailed our approach to implement such a plan in existing credited engineering curriculum: a multi-semester interdisciplinary engineering project sequence as the experience, and a two-semester seminar sequence to formulate objectives, foster reflective observation and further abstract conceptualization. We have formalized our plan responding to a college-wide initiative requiring students who entered as of fall 2015 to complete an experiential learning activity prior to graduation. Results of our pilot group students have been in progress, revealing the need to adjust due dates to ensure quality. Interdisciplinary projects presented here sample some of the many impactful service-oriented learning experiences students can choose, providing rich opportunities for growth personally, academically and professionally.

For faculty at other institutions who wish to formalize experiential learning associated with project work, this paper should help by providing some useful resources, assistance by example in thinking through the issues and lessons transferable to another institutional context.

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Appendix: Experiential Learning Initiative (ELI) Resources

A.1 Additional ELI Reflection Questions (AERQs)

1. *Discuss a significant moment during this experience that left a lasting impact on you. Why was this experience significant for you?*
2. *What did you learn about your strengths and weaknesses? What did you discover about yourself as a person…*
    a. *Professionally?* b. *Intellectually?* c. *Personally?*
3. *How did this experience influence your specific career/vocational goals?*
4. *Please provide specific examples of two transferable skills (i.e. skills that you will be able to use beyond your ELI / IPC project experience) that you gained or enhanced during your ELI (IPC experience).*
    a. *Transferable Skill 1: _______________________*
    b. *Transferable Skill 2: _______________________*
5. *Describe a problem that you faced or observed during your ELI / IPC project experience with your group. Describe the problem, and articulate an approach you would take toward a solution to the problem.*
6. *Please provide one example of something that you had learned in a course at Messiah (e.g. a theory, concept, strategy, etc.) that you were able to apply during your ELI (IPC project experience).*
7. *How did your ELI / IPC project experience deepen your understanding of your major and your broader educational experience (inside or outside of the classroom) at Messiah? How does your ELI / IPC project experience apply to your major and/or future courses?*
8. *As a result of your experience in the ELI / IPC, what is one specific way you foresee your future self…*
    a. *Contributing to your community over the long-term?*
    b. *Having purposeful influence in church and society?*
    c. *Pursuing the work of reconciling individuals with God, each other, and/or creation?*
    d. *Demonstrating the love of God in service to others?*

A.2 Messiah College's Assessment Rubric for ELI Experience including the correlated College Wide Educational Objective (CWEO). Each student must obtain at least eight (8) points on this rubric to fulfill the ELI requirement (continued on next page below).

OUTCOME **Points**	**CWEO**	**DIMENSION** (Mapped to final reflection question numbers)	**DEFINITION** (Proficiency Level)	**NO ATTE MPT** **0**	**NEEDS IMPROVE-MENT** **.5**	**PROFI-CIENT** **1**	**EXEMP-LARY** **1.25**
Meaning-ful **Careers**	5.d - interests, abilities, and limitations	Identifying Personal Strengths /Abilities (Questions 1, 2, & 5)	Student clearly and accurately connects their intellectual, professional and personal strengths and abilities to their ELI experience				
	5.c.- sense of vocation/ca-reer that transcends career choice	Sense of Vocation (Questions 3 & 4)	Student clearly articulates how their experience enhances or informs their vocation (sense of purpose for their interests& abilities)				
	Academic integration 4 – major 1-3, 5-7 – QuEST	Academic Integration (Questions 6 & 7)	Student identifies specific ways in which academic learning informs ELI experience and/or ELI experience informs classroom learning				
Commun-ity & Calling	5.e. - role in community	Role in Community (Question 8a)	Student develops and specifically demo's awareness of his/her role, both personally & professionally, in society				
	7.b. Leadership - civic responsibility	Leadership (Question 8b)	"Student identifies specific ways in which (s)he does or could have purposeful influence in the broader church and society" (def. of				

Community Engagement			leadership from MC Leadership Model)				
	7.c. – Reconciliation- acting responsibly and redemptively	Reconciliation (Question 8c)	Student identifies specific ways in which (s)he does or could seek to pursue the work of reconciling individuals with God, with each other, and with all of creation in the broader church and society" (definition of reconciliation from MC foundational values document)				
	7.f. - Service - decisions based on ethic of service	Service (Question 8d)	"Student identifies specific ways in which (s)he does or could seek to demonstrate the love of God in service to others" (service phrasing from MC foundational values document)				
Completion of Deliverable			Student has completed deliverable project in the format appropriate to bucket area and in a way that clearly summarizes ELI outcomes and reflections to an external audience				