An Industrial Engineering Design Experience Reflecting upon Moral Development and Wellbeing

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Abstract

Typical design projects in the Industrial Engineering (IE) curriculum use a systematic process improvement methodology to solve problems for the manufacturing or service industries, where students have an opportunity to apply the knowledge gained through coursework in a real-world environment. While these projects are often assessed in terms of technical efficiency and course outcomes, less often do they assess experiential dimensions, such as the students' reflections on the process, their engagement with the people involved (i.e. workers, users, affected communities), or their commitment towards ethical values and social responsibility. This work describes the reflections about a non-traditional junior year design experience, for a group of 45 industrial engineering students who worked in 13 teams, and completed a set of self-reflection discussion questions as part of the post-project experience evaluation. A participatory design experience in local coffee farms provided a novel and positive experience, helping students to better understand the IE profession and its scope. Content analysis framework was used to: summarize the students' responses into trends and common ideas, quantify the impact of the experience, and uncover common themes across student responses. Findings show that the experience was novel for students, they envisioned how Industrial Engineers (IEs) can influence society and well-being, and that the project positively impacted their skills, knowledge, as well as their personal and professional development. The reflections show that 49% of students believed that the proposed recommendations in their project impact well-being, and more than 30% perceived that IEs could influence society and well-being through creating safer working environments. Findings show strong evidence that the experience helped students gain a better understanding of ergonomic-related applications within the IE field. Students perceived that the project helped them refine or develop teamwork, communication, critical thinking and interpersonal skills, as well as intuition, empathy, commitment, and leadership. Results also show students' engagement at three different levels of moral development, including value realization, prevention and integration, as well as insights from a perspective of capabilities approach and social well-being with an emphasis on bodily health. Rubrics for project proposal, final written report and poster are included as part of the documentation for the project evaluation.

Key Words: project-based learning, engineering education, engineering design, social responsibility, well-being

Introduction

Design projects within Industrial Engineering (IE) typically provide students with "real-world" experiences in the manufacturing or service industries. Corresponding assessment emphasizes technical efficiency and skills obtained by the participating students. These projects generally follow a cyclical analysis methodology for process improvement that guides analysts to define the problem, measure, analyze, implement and control. This process, known as Six Sigma DMAIC, requires a clearly defined problem, goals and corresponding metrics to monitor progress (Lynch, Bertolino, & Cloutier, 2003). The problem statement and goals are typically defined by consultants, team leaders or supervisors, disregarding the insights from external stakeholders (i.e. consumers, end users, workers or affected communities). However, these projects usually do not assess students' reflections of the

experience, their engagement with stakeholders or commitment towards ethical values and social responsibility. In particular, the explicit use of guided self-reflections as part of the post-project evaluation and design activities is seldom incorporated. These limitations, perhaps, correspond with the relative lack of ethical and community consciousness among engineering students observed by Cech (2014).

To foster student engagement with the broader contexts that surround engineering design projects, a project at the University of Puerto Rico-Mayagüez Campus, funded by a National Science Foundation grant (Castro-Sitiriche, Papadopoulos, Frey, Santiago-Roman, & Jimenez, 2014), seeks to embed social, ethical and global issues (SEGI) within the engineering curriculum. The NSF project titled "Cultivating Responsible Wellbeing in STEM: Social Engagement through Personal Ethics" (CRWS) aims for students to substantively incorporate SEGI's as non-trivial constraints in their design procedures and decisions. To advance these goals, the CRWS project employs principles such as: Responsible Well-being (Castro-Sitiriche, Papadopoulos, Frey, Santiago-Roman, & Jimenez, 2014), Appropriate Technology (Willoughby, 1990; Schumacher, 1973), the Capabilities Approach (Oosterlaken, 2015; Nussbaum, 2011), Value Sensitive Design (Oosterlaken, 2015), and Participatory Action Research (Oosterlaken, 2015), in its research and educational activities.

This work describes one of the educational activities associated with the CRWS project, in which several of the aforementioned issues were effectively integrated into a novel, junior year design experience. This was achieved through the Work Systems Design Course, in which students learn about Ergonomics and Methods Engineering as part of the Industrial Engineering Program Curriculum. The project immersed students in coffee harvesting or processing in an actual working environment in the coffee industry.

Ergonomics, an area of study within the IE field, is defined as the application of scientific principles, methods and data drawn from a variety of disciplines to the development of engineering systems in which people play a significant role (Kroemer, Kroemer, & Kroemer-Elbert, 2001). The evaluation of a system with a primary focus in the human element, makes the area of ergonomics ideal for the study of work environments outside traditional manufacturing or service industries, such as the coffee industry in this case. Indeed, the coffee industry provided a great opportunity to apply ergonomic tools using a participatory research approach and engaging students to develop ethical values, sensibility as well as social responsibility.

The design experience was centered around Participatory Action Research, which can be defined as "systematic inquiry, with the collaboration of those affected by the issue being studied, for purposes of education and taking action or effecting change" (Green, et al., 2003). In this particular case, students were provided with an opportunity to directly interact with stakeholders to define goals and identify a problem statement through an action research methodology.

Course Description

The Work Systems Design course at the University of Puerto Rico-Mayagüez Campus, provides junior-level students their first formal design experience in the IE Program Curriculum. The course prepares students in work systems design where human beings play an important role. This is accomplished through the alignment of systems, jobs, products and

environmental conditions to the characteristics and human abilities to achieve mental and physical well-being. The expected course outcomes include: (1) application of design strategies for work systems design, (2) design of products, workstations and systems using data and design principles, (3) evaluation of the physiological requirements of a task, (4) identification of occupational risk factors, and (5) evaluation, enhancement or design of work systems following ergonomic principles. The course is a core 4 credit course (75 contact hours) with guided laboratory activities and a required design project. Typically, the course project is defined by the course instructor and can vary between a case study, classroom projects or projects in service or manufacturing industry (Pomales-Garcia & Cortes, 2014). In this particular scenario, the project weight was 17% of the final course grade and required a proposal, a final written report and an oral presentation using a poster format. Course activities incorporated the use of rubrics for evaluation purposes (see Appendix A-C).

Methodology

In 2015, a group of 45 Industrial Engineering undergraduate students (22 females and 23 males) had the opportunity to complete the Work Systems Design course project in the coffee industry with a primary focus on participatory research. Students had the task of applying the work design course knowledge in an agricultural task as a means to achieve the course learning outcomes.

During a three (3) month period, students worked in one of 13 teams of 3 or 4 students each (assigned by the course instructor), to evaluate different tasks in the coffee industry (i.e. coffee harvesting or coffee processing), identify risks associated with each task and propose recommendations. The different tasks evaluated by the students were: the coffee picking, fruit weighing and processing, milling or hulling, or roasting and storage. After the initial group visit with the course instructor, each team had to draft a proposal inspired by a particular task and were required to visit the project location at least three (3) times. The project's process, activities and deliverables (summarized in Figure 1) include the following steps: (1) participate in a group visit to the farm with the course instructor to understand the process and choose a task of interest, (2) build a rapport with workers to find out their needs, (3) understand the work system and process, (4) define problem with specific and measurable objectives for the project, (5) gather data aligned with project objectives, (6) propose recommendations based on observations and data collected, (7) evaluate the impact of such recommendations and make improvements, if needed, and (8) present project results to an audience using written and oral formats.

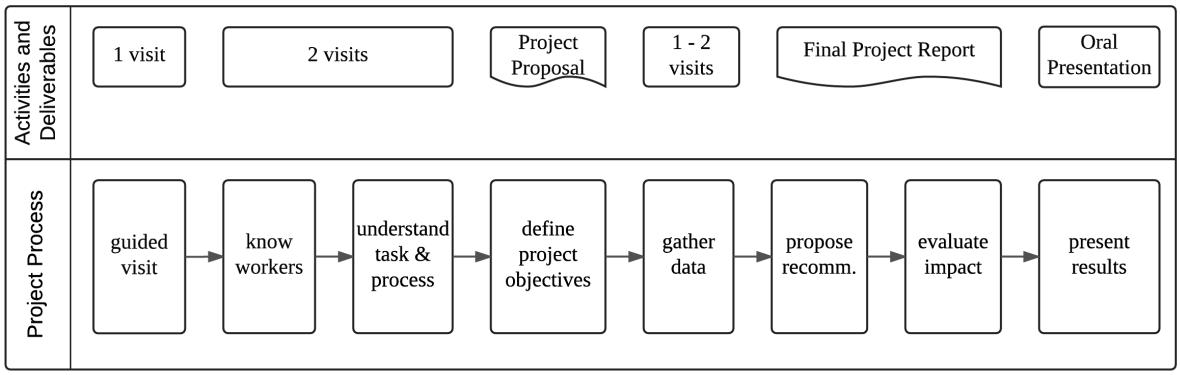

Figure 1. Project activities and deliverables as an integrated process

The project proposal was evaluated using a rubric (Appendix A) and detailed comments on project scope and objectives were provided to students as a midterm feedback process. At the end of the semester, each team delivered a written report and presented a poster which highlighted their methods, findings and recommendations. The written reports were evaluated by the course instructor using a project rubric (Appendix B) specifically designed for the course. The oral poster presentations were evaluated by a panel of judges using an oral presentation rubric (Appendix C). The panel judges included the course instructor, an invited instructor, farm personnel and subject matter experts from the local agricultural experiment station. The project context and the experience was novel for students in the IE program, therefore we consider the project as non-traditional. This served as a motivational agent to produce projects with a strong technical foundation, meaningful experience, and highly creative recommendations.

At the end of the course, students had to reflect about their learning and experiences by answering a series of nine (9) open-ended discussion questions and nine (9) closed survey questions, presented in Table 1, with their corresponding instructions. The questionnaire was designed as a self-reflection instrument to understand the impact of the project in student learning, and gain insights from their personal and professional experience, as a post-project reflection activity. The discussion questions were written in English and translated to Spanish, giving students the opportunity to respond in either language. The closed survey questions, related to skills and relevance of the experience, included statements for students to agree or disagree, using a 5-point Likert Scale. Students had to submit their responses to the questions using an online course management system as an appendix to the course project. The reflection was a requirement of the course project and was graded upon delivery, not content. Similar approaches, incorporating reflections or reflective journals have been used in service learning ("Carin" Chuang & Chen, 2013), project based learning activities (Dunlap, 2005) and with increasing interest in publications related to engineering education in general (Sepp, 2015).

Content analysis methodology was used to summarize the responses into trends and common ideas, to quantify the impact of the experience and uncover common themes across students' responses. Two raters, were trained in content analysis methodology and independently evaluated the themes present in the survey question responses. During the individual evaluation, they independently extracted common ideas or keywords within the written discussion questions and aligned individual responses under each of the keywords identified. Then, the two raters joined with a third external evaluator who analyzed their proposed keywords and the corresponding alignment between student responses and keywords. The external evaluator and raters worked in collaboration to integrate the two independent analyses into a final set of keywords and responses. Proportion of responses by questions were used as a means to uncover response trends. Examples of student responses are provided to support the findings. Also, an analysis of responses in alignment to the different skills of moral development (Cruz & Frey, 2003) and Capabilities Approach (Nussbaum, 2011) are discussed to deepen the analysis within the context of the ethical values of well-being, agency, and justice (Oosterlaken, 2015).

Table 1. Contents of Survey Questions

The following questions are designed to help me understand the personal and professional impact of the work systems design course project in an agricultural environment. All questions relate to your experiences in the design project. Your responses will not be evaluated based on the particular answers, but only on delivery of the document. Please be honest in your response. Answers provided to the questions will be summarized and analyzed in aggregate manner, no personal identifiers, other than gender, will be used in the data analysis. The class responses to these questions may be used for research activities. You can answer the questions in English or Spanish.

Open Survey Questions

Q1. (Project Experience) How do you feel about the experience of completing your Work Systems Design Project in an agricultural environment? *¿Cómo te sientes sobre la experiencia de realizar tu proyecto de diseño de sistemas de trabajo en un ambiente de agricultura?*

Q2. (IEs influence in society and well-being) From your experience in the project, what influence can Industrial Engineers have to impact society and the well-being of others? *¿Basado en tu experiencia en el proyecto, qué influencia pueden tener los Ingenieros Industriales en impactar la sociedad y el bienestar de los demás?*

Q3. (Impact in consumption and well-being) Do you believe that your proposed recommendations in the project impact consumption and well-being? Explain your response. *¿Crees que las recomendaciones propuestas en tu proyecto tienen un impacto en el consumo de bienes y el bienestar?*

Q4. (Personal and professional impact) Do you believe this project has made an impact in your personal and professional life? Explain how. *¿Crees que este proyecto ha tenido un impacto en tu vida personal y profesional? Explica cómo.*

Q5. (New things learned) Identify 3 new things that you learned through this project. *Identifica 3 cosas nuevas que aprendiste a través del proyecto.*

Q6. (Skills, ideas and knowledge reinforced) Identify 3 things/ideas/knowledge that you reinforced through this project. *Identifica 3 cosas, ideas, conocimiento que reforzaste mediante este proyecto.*

Q7. (Skills, ideas and knowledge reinforced) Identify several skills that you gained or refined as part of the project. *Identifica varias destrezas que ganaste o refinaste como parte del proyecto.*

Q8. (Keys for success) What helped you to succeed in your project? *¿Qué te ayudó a ser exitoso(a) en el proyecto?*

Q9. (Value) How do you value what you learned from the process and the project? ¿Qué valor tiene para ti lo que aprendiste en el proceso y el proyecto?

Closed Survey Questions

(The scale used by students consisted of the following alternatives: 5: Completely Agree, 4: Agree, 3: Neutral, 2: Disagree, 1: Completely Disagree.)

(1) This project helped me develop technical and professional skills to practice the IE profession (Technical)
(2) The group work in this project helped me develop interdisciplinary teamwork skills (Teamwork)
(3) The oral reports and presentations helped me develop oral communications skills (Oral Comm.)
(4) The written reports helped me develop written communications skills (Written Comm.)
(5) This project allowed me to take ethical issues into consideration, as part of the design process (Ethics)

(6) This project allowed me to take legal issues into consideration, as part of the design process (Legal)
(7) This project allowed me to take societal issues into consideration, as part of the design process (Social)
(8) This real-world project experience was a successful complement to the IE educational process (Complement)
(9) This project allowed me to integrate the principles, methods, and techniques of earlier course work into a real-world problem solving situation (Real-World).

Findings

Table 2 shows the results for the open discussion questions using content analysis. Relevant themes identified within students' reflections are presented and grouped according to the proportion of participants who had common ideas. Content analysis results are presented in quotations to specify literal terms used by students in their response, as opposed to themes created by the authors to represent ideas extracted from the analysis. All students' responses have been translated to English in order to facilitate discussion of results.

Corresponding to the project experience (Q1), 93% (N=41) of students reported a positive experience with the project and the process, as they were able to better understand the profession and its scope. Some representative student comments about their experience include the following:

"The experience of conducting the project in an agricultural setting was excellent, as for the first time I have been able to apply my knowledge in a system different to Industry."

"The experience of the project in "la Hacienda" was completely new and interesting, without a doubt, I was able to observe and learn how IE is not only about industry, but it can also be applied in agriculture"

"The experience was very pleasant; I have never been exposed to this environment … in this area there is a need for lot of help, as we identified many opportunities to improve the system and this means that the experience will help me greatly in the future."

Interestingly, these comments suggest that IE students view agriculture as a sphere separate from "industry". Regardless of whether they now view agriculture as an industry, it is clear that the project exposed them to a new environment.

Results for Industrial Engineers' (IEs) influence on society and well-being (Q2), show that more than 30% of the students perceived that IEs made an impact by creating safer working environments. Students discussed that safer working environments can be achieved through the reduction of work intensity, effort, and work-related risks and injuries. They also mentioned that increasing worker comfort and easing work activities will promote a safer working environment. Several representative comments are as follows:

"*IEs can impact the well-being of workers by giving them safer working environments. We have the tools to analyze current tasks, identify flaws, and correct them".*

"IEs can positively influence society and well-being as we are somewhat responsible [for determining] that work equipment [being used] is the correct one"

"As IEs we have the tools to enhance the quality of life, reducing risks and enhancing processes in all aspects…we have an instinct for improvement that needs to be present and be used for the well-being of others".

"…compared with other engineering fields, within IE, well-being is one of the basic parameters considered when changes to a design, process or method is proposed"

Table 2. Content analysis results for open-ended questions

Reflection Questions	**Content Analysis** (*>10%, **>20%, ***>30%, ****>40%)
Project experience (Q1)	"new experience"**; "liked, pleased"**; "different"*; "challenging, difficult"*; "satisfied, gratifying"*; "good"*; "interesting" *
IEs influence in society and well-being (Q2)	Simplify, enhance, redesign effectively (designs, processes, procedures, work stations, equipment, production and services)****; efficiency, comfort, work-life****; safer working environments***; physical, mental and economic well-being and worker health**; use of ergonomics*, identification of muscular skeletal disorders and avoiding risks for injury*; augment, maximizes, simplify or optimize productivity, cost, and efficiency *; implement knowledge and methods learned as well as analysis techniques *; improve facilitate quality of life of humans *
Impact in consumption and well-being (Q3)	Yes****; Worker safety, comfort and well-being****; Product cost and worker wages****; Methods tools and equipment****; Productivity and quality**
Personal and Professional impact (Q4)	Understand the challenges in the work****; first experience to apply knowledge*** working in a team**; communication skills**; problem solving*
New things learned (Q5)	Implementation of knowledge, methods learned and analysis techniques****; coffee process****; communication with workers and team members*; challenges in agricultural work*; data collection and analysis *
Skills, ideas and knowledge reinforced (Q6-7)	Teamwork and oral communication****; patience, interpersonal relations, intuition and empathy**; specific concepts and techniques presented in the course**; relevance of interviews*; critical thinking*
Keys for success (Q8)	Teamwork****; instructor mentoring and laboratory activities*; responsibility*
Value (Q9)	First experience with strong professional component****; understand diversity and importance of IEs in a work environment*

Also, close to half of the group (49%) directly asserted that their proposed recommendations in the project would impact consumption and well-being (Q3). A considerable group of students (67%) framed well-being from a standpoint of worker safety, comfort and reduced effort, 47% focused on work methods, tools and equipment, and a few (29%) focused their response on increased productivity and quality as a means to achieve well-being. On the other hand, 42% of students associated consumption and well-being with reduction of costs and increase of wages.

Students agreed that the project had an impact in their personal and professional life (Q4). Over 40% of students were more attuned with the reality of agricultural work and expressed both increased knowledge about agriculture and empathy for agricultural workers. One student captured this well, saying *"how difficult is the task of coffee collection, the low wages for agricultural workers, the need to interact and relate to others as part of the project, the sacrifices involved in agricultural work and admiration they felt for others in this line of work"*. Also, students shared that they now have a better understanding of applications within the IE field and profession (44%). In particular, they made emphasis in specific methods and tools used for analysis (i.e. Rapid Upper Limb Assessment, DMAIC, learning curves, NIOSH lifting equation, push-pull analysis, energy consumption analysis, flow diagrams, statistical analysis techniques (e.g. ANOVA), biomechanical analysis, and anthropometric measurement techniques).

Important skills, ideas and knowledge gained or refined in the project (Q5-Q7) include teamwork (47%), communication skills (33%) and people skills (20%). Other skills mentioned by few students include problem solving, critical thinking, creativity, time management, observation, and information skills. It is also relevant to highlight that few students included important values as relevant skills, such as perseverance, responsibility, empathy, commitment, and leadership. This shows that the project experience was complex and rich, with respect to creating opportunities for students to develop multiple crucial professional skills.

According to students, the keys for success in the project (Q8) was teamwork (64%), as described in the reflections through *"fellowship, active listening, dedication, shared initiative, diverse personalities, assertiveness, support, creativity, positive attitude, availability, team effort, work ethic and shared work"*.

Finally, the value of the process and the project (Q9) was mostly professional, to gain experience in the design process (40%) and be able to *"glimpse into the professional future" ... "so that I can make a difference",* as shared by a student.

Figure 2 shows the average rating for each of the closed survey questions, designed to understand the impact of the project in the students' learning, and gain insights from their personal and professional experience. Average ratings for all statements are above 4 in a 5-point scale. Standard deviation in average scores was between 0.5 and 1.09 points, with highest differences in questions, corresponding to consideration legal issues as part of the design process. A detailed analysis of responses (shown in Table 3) demonstrates that in this particular question, 9% of students either disagree or completely disagree with the statement provided. No noticeable differences were identified by gender, but some differences were observed by course grade. Students with final "A" grade, tended to rate their response lower in comparison to students with "C" grade. An exception was observed in "successful experience of project to complement the IE education" and "use of written reports to develop written communication skills", in which students with C grade ranked much lower than students with A grade (0.71 and 0.38, respectively).

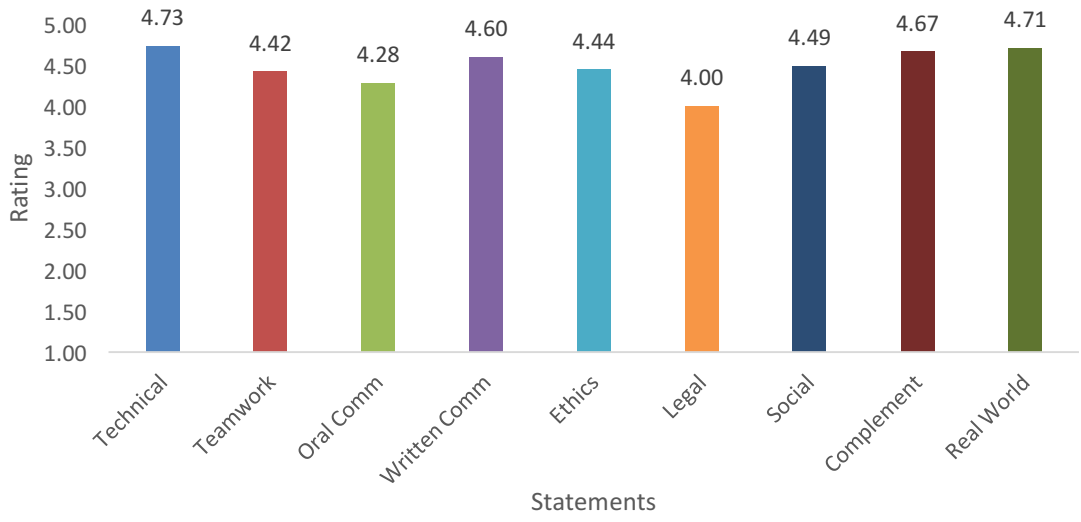

Figure 2. Average scores for closed survey questions

Table 3. Summary of responses for closed questions

Closed survey statements	Positive	Neutral	Negative
(1) This project helped me develop technical and professional skills to practice the IE profession.	98%	2%	0%
(2) The group work in this project helped me develop interdisciplinary teamwork skills.	84%	13%	2%
(3) The oral reports and presentations helped me develop oral communications skills.	81%	19%	0%
(4) The written reports helped me develop written communications skills.	96%	4%	0%
(5) This project allowed me to take into consideration ethical issues as part of the design process.	87%	11%	2%
(6) This project allowed me to take into consideration legal issues as part of the design process.	73%	18%	9%
(7) This project allowed me to take into consideration societal issues as part of the design process.	89%	11%	0%
(8) This real-world project experience was a successful complement to the ININ educational process.	96%	4%	0%
(9) This project allowed me to integrate the principles, methods, and techniques of earlier course work into a real-world problem solving situation.	98%	0%	2%

A comparison between student responses to open-ended and closed survey questions (shown in Table 4) only show a strong relationship between in responses related to *project experience* (Open Ended Question Q1 and Closed Survey Question Q8). Other questions related to social, technical/professional skills, knowledge and value showed a difference (40%-58%) between the student agreement for the closed survey questions and students discussions for the open-ended questions. Also, some open-ended questions had no direct link with particular outcomes evaluated in the closed questions (i.e. New things learned (Q5) and keys for success (Q8)).

Table 4. Comparison of responses between open-ended and closed survey questions

Questions		Results		Difference
Open Ended	Closed Survey	Open Ended	Closed Survey	
Project experience (Q1)	Complement(Q8)	93%	96%	3%
IEs influence in society and well-being (Q2)	Social (Q7)	49%	89%	40%
Impact in consumption and well-being (Q3)	--	67%	--	--
Personal and Professional impact (Q4)	Technical (Q1)	44%	98%	54%
New things learned (Q5)	--	44%	--	--
Skills, ideas and knowledge reinforced (Q6-7)	Teamwork (Q2), Oral Communication (Q3), Written Communication (Q4), Real World (Q9)	47%	90%	43%
Keys for success (Q8)	--	64%	--	--
Value (Q9)	Real World (Q9)	40%	98%	58%
--	Ethics (Q5)	--	87%	--
--	Legal (Q6)	--	73%	--

Discussion and Conclusions

The findings show the richness of experiences gathered from students' reflection during project experiences, instead of solely inquiring about concepts or ideas learned during the course. Indeed, it is through such introspection that students develop the capabilities that secure self-transcendence and generate meaning (Harris, 2015), helping them to form a conception of their future career as IEs. There was awareness of the agricultural industry, an empathy for agricultural workers, and a sense of how IEs can work to improve work conditions. Arguably, in the absence of such reflection, students are less likely to attach a sense of mission to their work.

There are a variety of frameworks to further interpret these encouraging results. Drawing from the field of Engineering Ethics, we appeal to five fundamental skills of ethical decision making, articulated by Cruz and Frey (2003). Because the Work Systems Design class does not include any explicit instruction or commentary related to ethical theory[1], it was not expected that students would appeal to ethical frameworks in their reflections. Nevertheless, the results indicate that an overwhelming 87% of the students demonstrated the first fundamental skill of "Awareness", which Cruz and Frey define as the "ability to perceive ethical issues in complex, concrete situations", and which has been reinterpreted as the "ability to identify social, ethical, and global issues and relevance in technologies and Socio-Technical Systems (STS)" (Castro-Sitiriche, Papadopoulos, Frey, Santiago-Roman, & Jimenez, 2014). One student captured this well, saying *"Fundamental IE knowledge (i.e. statistics, organizational behavior, ergonomics and economics), give us the ability to improve and ease the life of human beings within society in response to the challenges imposed by technology and environment."* Thus, even without using formal or precise language from

[1] Presumably most students have had an elementary exposure to ethical reasoning as a result of the required 2-hour module that is included in the Freshman year. Furthermore, many students elect to take the University's course in Engineering Ethics.

ethical theory, students were able to understand that their work was embedded in a larger context than the technical aspects of ergonomics.

Beyond the basic skill of "Awareness", the skills articulated by Cruz and Frey (2003) suggest the use of ethical frameworks for comparing between given alternatives ("Evaluation"), anticipating ethical problems at the early design stages and foreseeing appropriate counter-measures ("Prevention"), integrating ethical values of the various stakeholders so they can exert "an essential, constitutive role in the final [design]" ("Integration"), and finally, "recognize and exploit opportunities for promoting personal and social well-being." An example for the latter would be enhancing "safety and health, improve environmental quality, and find appropriate technologies and practices that realize better living conditions" ("Value Realization"). In the CRWS Project, these skills were broadened to include other frameworks beyond traditional ethical theories, including Value Sensitive Design, the Capabilities approach, and Participatory Action Research. Although the students were not provided explicit instruction in these methods (though, as noted, Participatory Action Research constitutes their experience), it is nevertheless clear that students' comments indicate their abilities across the fundamental skillset. Certainly, as the project had a strong safety and health component, students applied "Prevention" when they evaluated the actual or perceived risks of a task and proposed corresponding countermeasures to mitigate or eliminate them. But perhaps most strikingly, numerous comments appealed to some aspect of "Value Realization". Indeed, students consistently shared that IEs can impact society and the well-being of others through the following ideas extracted from the reflections: *"process simplification to avoid cumulative trauma disorders", "a vision for process improvement where humans can feel comfortable and increase their productivity, supporting quality of life", "linking economics, feelings, well-being and efficiency … as important variables in the equation", "realization that our actions and lives have risks", "responsible of selecting the correct equipment", "the work system works like a domino effect; workers can [do their jobs] more effectively and without much risk to their well-being, then production rates increase, and ultimately the company is more prosperous".*

Prevention, considered as the ability to uncover ethical problems through a socio-technical analysis and to solve them by designing counter-measures (to the problem), early in the design process (Cruz & Frey, 2003; Castro-Sitiriche, Papadopoulos, Frey, Santiago-Roman, & Jimenez, 2014), was evident in the relationship between *"worker safety, comfort, effort and risk reduction"* identified by the students as the end in the design activity, and ultimately attained through the process improvement.

Integration or the ability to treat social, ethical, and global value as goals in the designing activity, such that one is able to generate designs that translate or realize these values (Cruz & Frey, 2003; Castro-Sitiriche, Papadopoulos, Frey, Santiago-Roman, & Jimenez, 2014), was demonstrated through students' ideas about their proposed recommendations and solutions to the project problem that would *"support the actual work process, reducing waste and increasing product quality";* as *"… solutions impact productivity with benefits to owner and worker, increasing production, impacting revenues and worker salary".*

The students' reflections can also be evaluated in terms of the Capabilities Approach. Nussbaum (2011) defines capabilities as the following: "The Capabilities Approach can be provisionally defined as an approach to comparative equality-of-life assessment and to theorizing about basic social justice. It holds that the key question to ask, when comparing societies and assessing them for their basic decency or justice is, "What is each person able to

do or be?" The capability approach emphasizes agency over need, providing a "powerful conceptual framework to assess and evaluate technology in terms of" the values of well-being, agency, and justice (Nussbaum, 2011). In the context of the agricultural workers, the project results and recommendations influenced their capabilities in the sense of bodily health and control over economic environments (Nussbaum, 2011) that relate upon physical and social capabilities (Harris, 2015).

Perhaps related to Capabilities, are values of Social Justice. Some students' recommendations highlighted social justice values by emphasizing the need to transform the current agricultural worker situation by removing obstacles that will allow them to reach a better quality of life. Some students' comments about the task or the profession, that exemplify social justice include:

> *"Agriculture is an activity that is vital for anyone, be it a nation, an island, or an individual, necessary for survival and independence but in such a crucial moment we take it for granted"*
>
> *"…if the worker is injured there will be no workers available and without them, the services offered and products suffer. Our recommendations focus on worker comfort"*
>
> *"The vision of process improvement where humans can be comfortable while improving their productivity is an immeasurable impact to the quality of life of human beings".*

In the language of Leydens et al. (2014), such students are operating well beyond the design for the "Specification" and even the "Client", and are embarking upon design for "Community" and for "Social Justice".

From the Participatory Research perspective, the project process allowed the community and students to reflect upon stakeholder benefits through creation of knowledge and awareness (during the final presentation), an opportunity for workers to participate in the creation of alternative work methods (student visits to the plantation), as well as improved practices and improvement of livelihoods (Neet & Neubert, 2011). These are characterized as relevant attributes within the stakeholder's benefit dimension.

In considering this course and project experience as a whole, it is suspected that the Engineering Curriculum can go further to elicit meaningful reflections from students as an integral part of their entire project experience. Rather than only relying on a post-project reflective experience, as was the case here, a new model (see Figure 3) that integrates a pre-reflection activity as a means to create a deep and meaningful reflection of the experience and process can be proposed. We hypothesize that a pre-reflection of socio-technical aspects in the project, early in the project process, will provide a space to reflect upon self-perceptions and expectations about the future experience. The pre-reflection would help to quantify and evaluate the social impact of the project and promote the development of ethical values and social responsibility in the Engineering Curriculum, which Cech has lamented, is in decline (2010). In the same line, an opportunity to engage students in a discussion of their process might enable a meaningful learning experience. Traditional approaches to teach ethics involve workshops and reflection activities where students evaluate cases from different lenses to identify ethical problems. In our experience, these approaches are not effective to engage students in a deep personal reflection, generate a personal connection, or at least, create empathy with stakeholders. Therefore, the creation of engaging, non-traditional experiences with a participatory research approach creates a rich environment to promote the development of those characteristics that will generate a responsible cadre of future engineers committed to practice their profession with strong foundation in social, ethical and global issues. Future

work should explore the difference in student reflections based on project type, as well as baseline data for students that did not complete the reflection.

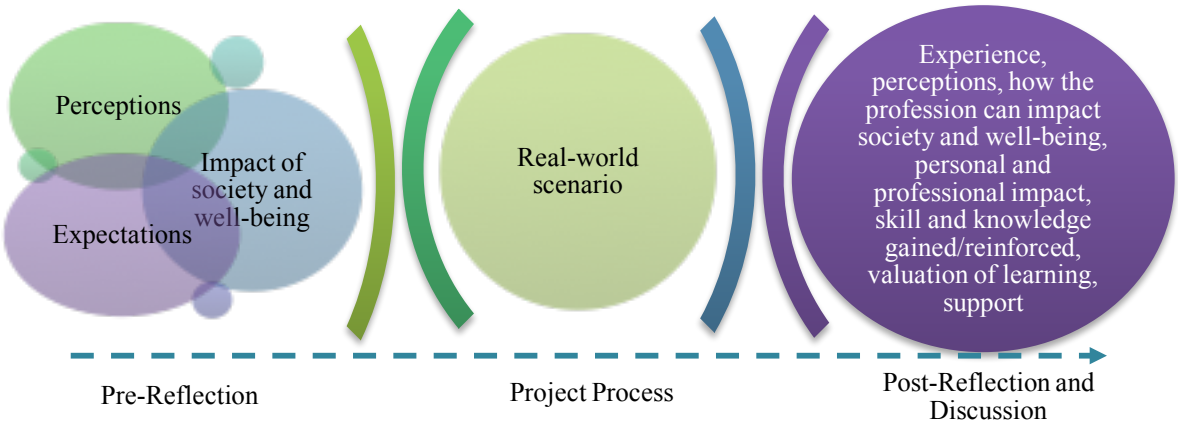

Figure 3. Proposed model to incorporate reflections in design projects

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Appendix A: Project Proposal Evaluation Rubric and Maximum Number of Points (#)

Letter of Transmittal
- Has proper and complete heading (1)
- Includes the information about the document that is being sent (1)
- Includes the title of the document, and the location where the project will be carried out (1)
- Provides complete company contact information: (name, title, address, telephone and email) (1)
- Includes team member's contact information (name, telephone, and email) with signatures (1)

Cover Page and Title
- The title is descriptive, in 12 words or less and encloses the main idea of the project (1)
- Correct University heading information (Name, campus, department, complete course title and course number) (1)
- Has names of team members (using alphabetical order) (1)

Project/Executive Summary
- Includes the title of the proposal and each team member's names in the page heading (1)
- Brief introduction and proposal justification/relevance is clear (3)
- Descriptive enough to have a good idea of the proposal content, its goals or objectives (2)
- Briefly includes the proposed methods to achieve the desired objectives (2)
- Briefly states the expected results or outcomes (2)

Introduction, Background and Problem Description
- Offers a good background to the proposal (presents scope, limitations and assumptions) (10)
- Includes relevant references of previous research work or cases (5)
- Clearly and briefly describes the task or job being studied and number of individuals involved or studied (5)
- Clearly and precisely explains the problem(s) in hand (2)
- Clearly explains problem motivation/justification and the need for the project (1)
- Cites relevant statistics (2)

Objectives
- Clearly lists/numbers specific and measurable objectives or research questions for the project (6)

Methods
- Briefly describes the workers (gender, age, and experience/skill) (5)
- Clear, detailed and exhaustive description of the methods and techniques proposed for data collection and analysis considering job/tasks and objectives (10)
- Explains in detail how the problem will be attacked, based on the selected methods (8)

Deliverables
- Lists what you expect to give the company/supervisor/workers as a result of the project (3)
- Brainstorm on a possible solution/deliverable (2)

References
- Includes at least 5 references (2)
- All are referenced in the text (1)
- Uses APA formatting (1)
- Follows guidelines for reference selection (1)

Figures and Tables
- Includes at least two relevant figures and/or tables to support the proposal (4)
- They all have proper headings and labels (1)
- They are all referenced in text and embedded in the document (1)

Technical Writing
- Spell check (2)
- Grammatically correct and sound (2)
- Clear and concise language (not flowery) (1)

Overall presentation and Style
- Cleanliness (1)
- Length: Maximum 5 pages (-1 for each additional page used over the limit)
- Format: (Font, Font Size, Line Spacing, Margins) (1)
- Page numbers (in bottom right corner) (0.5)
- Title is capitalized (all letters and centered) with an abbreviated title in caps on all pages starting in the second aligned at the top, flush left. (0.5)

Appendix B: Final Project Evaluation Rubric and Maximum Number of Points (#)

Letter of Transmittal

Has a complete heading and includes the information about the document that is being sent (0.5)
Includes the title of the document, and the location where the project will be carried out (0.5)
Provides complete supervisor contact information: (name, title, address, telephone and email) (0.5)
Includes team member's contact information (name, telephone, and email) with signatures (0.5)

Cover Page and Title

Is the title descriptive and 12 words or less? (0.5)
Encloses the main idea of the project (0.5)
Correct University heading information (Name, campus, department, course title and number) (1)
Has names of team members (using alphabetical order)

Project/Executive Summary

Includes the correct title and each team member's names in the page heading (1)
Brief introduction is clear (2)
Briefly includes the methods used and important results (2)
Presents a clear summary of recommendations for improvement and relevant costs (1)
Descriptive enough to have a good idea of the project content, its goals and outcomes (2)

Introduction, Background and Problem Description

Offers a good background to the project (presents scope, limitations and assumptions, cites relevant statistics and correctly referenced material) (5)
Clearly and precisely explains the problem(s) in hand (2)
Clearly explains problem motivation/justification and the need for the project (1)
Clearly lists measurable objectives or research questions for the project (2)

Methods

Clear and detailed description of the methods used for data collection and analysis considering job/tasks and appropriate techniques (10)
Briefly describe workers (gender, age, experience/skill and relevant physical measurements) (3)

Results

Describes a solution in detail, considering the problem and project objectives (10)
Clearly shows the differences before and after the analysis (5)
Summarizes the recommendations for improvement (short and long term) (5)
Presents cost analysis and/or savings based on recommendations which are aligned with company/supervisor/worker needs (5)

Conclusion

All ideas are brought to an end (Not a summary of the project) (2)
Clearly explains the benefits of this project (to society, industry, individual) (3)

References

Includes at least 5 references in APA formatting (3)
All are referenced in the text (1)

Appendix

A. Includes signed consent forms from all the workers (1.5)
B. Summary of raw data collected in a separate file (1.5)
C. Original/copies of questionnaires, interview results and checklists used (3)
D. Suggestions for equipment with description, brand, model number and cost (3)
E. Project Summary Table (3)
F. Additional relevant information (i.e. Peer evaluation)
G. Individual Reflection and self-evaluation: Submits answers to Student Self-Reflection and Self-Assessment reflecting on the lessons learned from the project and experience (5)

Figures and Tables

Includes figures and tables to support the project and results (2)
They all have proper headings and labels (1)
They are all referenced in text and embedded in the project (1)

Technical Writing

Spell check (2)
Grammatically correct and sound (2)
Clear and concise language (not flowery) (1)

Overall presentation and Style

Length: Maximum 10 pages (-1 for each additional page used over the limit)
Format: (Font, Font Size, Line Spacing, Margins) (1)
Page numbers (in bottom right corner) (0.5)
Title is capitalized (all letters and centered) with an abbreviated title in caps should be placed on all pages starting in the second aligned at the top, flush left. (0.5)

External evaluation

This evaluation is from the viewpoint of stakeholders/supervisors. Each item will be ranked in a scale of 1 – 5 (1=poor, 5=excellent) for the items below at the time of the presentation:

A. Professionalism (visits to the work environment and interaction with employees)
B. Quality of work and clarity in delivery
C. Proposed solutions match expectations
D. General satisfaction with the work and project outcomes

Appendix C: Poster Presentation Rubric

Category	4	3	2	1
Questions and Knowledge	The group answered with excellence all questions about the poster.	The group answered appropriately all questions about the poster.	The group answered the questions about the poster.	The group answered the questions about the poster but the responses were not acceptable or clear.
Enthusiasm and Preparation	Facial expressions and body language of students generated great interest and enthusiasm about the topic. The group was completely prepared to present the poster.	Facial expressions and body language of students generated some interest and enthusiasm about the topic. The group was prepared to present the poster, although they needed more practice.	Facial expressions and body language of students generated poor interest and enthusiasm about the topic. The group was somewhat prepared to present the poster and they needed more practice.	Facial expressions and body language of students did not generate interest or enthusiasm about the topic. The group was not prepared to present the poster.
Vocabulary	I could understand without problems all information presented in the poster.	In general, I could understand without significant problems all information presented in the poster.	Some of the vocabulary or content used was complex, but I was able understand the information presented in the poster.	I did not understand the information presented in the poster.
Content Organization	The poster content was extremely organized, eye-catching and very easy to read.	The poster content was organized, but some words had small font that made it difficult to read.	The poster content had some organization problems and was difficult to read.	The poster content was very disorganized and was very difficult to understand and read.
Objectives	The objectives were extremely clear and adequate for the project and the problem.	The objectives were clear and adequate for the project and the problem.	The objectives were not clear and confusing.	The objectives for the project were not presented or they are not relevant to the project or problem.
Results	The design alternatives provide solutions to all problems and objectives, and they are creative, complete and very acceptable given the project needs.	The design alternatives provide solutions to some problems and objectives, they are creative, complete and acceptable given the project needs.	The design alternatives provide solutions to problems and objectives, but they are not creative, complete or acceptable given the project needs.	The design alternatives do not solve all the problems identified or are not creative, complete, or acceptable given the project needs.
General Evaluation	The project and poster is excellent and the best of all of those presented.	The project and poster is good and in the top 3 of all of those presented.	The project and poster is acceptable and in the top 5 of all of those presented.	The project and poser need to improve.