# Embedding Lifelong Learning in Engineering Courses

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# Embedding Lifelong Learning in Engineering Courses

**Abstract**

The main thrust of this paper is presenting an assessment methodology for lifelong learning competency. Several assessment tools embedded in a selected set of engineering courses along with their assessment methodologies, data analysis and conclusions are presented in this manuscript. The selected courses are spread over at the sophomore, junior, and senior levels. The courses include Engineering Dynamics, Fluid Mechanics, Propulsion Systems, and the Senior Design Capstone project. With the exception of the last course, students were assigned a set of open-ended problems that involved a wide range of engineering and real-world applications that students might encounter as practicing engineers or as graduate students. Information sources were restricted to peer-reviewed published work such as journal articles, conference proceedings, and books. Students were directed to use the main engineering digital databases Engineering Village or Compendex, which provide comprehensive coverage of literature in all engineering fields. Unsupported assertions or claims were a basis of rejection or grade reduction of the project grade. The attainment level of the lifelong learning competency was assessed using two performance indicators. The first performance indicator comprised of measures of students' ability to recognize the attributes of a lifelong learner, the significance of lifelong learning, and identification of sources for continuing education. This performance indicator was assessed using a comprehensive online survey that students filled out upon completion of the research project. The second indicator focused on students' ability to independently perform an in-depth analysis, produce quality work, and use various resources to learn new material not taught in class. This performance indicator was assessed using technical report grading rubrics. Students' feedback, survey, and reports analysis, all indicated that the methodology has been successfully implemented. The awareness level of attributes of being a lifelong learner, identification of different means of lifelong sources and methods have been positively impacted.

## Lifelong Learning – Motivations and Definition

ABET[1] and the National Academy of Engineering (NAE)[2] have established a set of attributes that engineering graduates should possess upon graduation. These attributes include both technical and non-technical skills and competencies that students are expected to know upon graduation. Generally, the latter is not as well-defined as the former, thus assessment of the non-technical competencies is more challenging and harder to assess.

The fast pace of advancement in science and technology makes it vital for all professionals to stay up-to-date with contemporary advances and innovations in various fields of technology. The multidisciplinary nature of engineering practice puts engineers at the forefront of meeting this pressing demand. At some point in their practice, engineers will need to solve a problem or design components that requires research, learning new software, knowledge of other engineering disciplines, or locating an article in a book, journal, or a conference proceeding.

Criterion 3i of the ABET 2000 and its subsequent revisions and modifications[1], requires that engineering graduates are expected to possess the competency of "*recognition of the need for, and an ability to engage in lifelong learning*". The theme of this criterion is to instill the ability

to learn how to learn. Philip Candy[3] defined lifelong learning as *"equipping people with skills and competencies required to continue their own self-education beyond the end of formal schooling"*. In a memorandum on lifelong learning the Commission of the European Communities defined lifelong learning as an *"all purposeful learning activity, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence"*[4].

**Strategy**

The assessment strategy outlined in the subsequent paragraphs is based on several engineering courses at the sophomore, junior, and senior levels. It is important to note that the procedure can be applied to any engineering course without changing the course structure or delivery methods. In the sophomore level Engineering Dynamics course, the assessment adds a short term research paper or the solution of an open-ended design problem addressing application of dynamics principles to applications such as sports, car crash test, seat belt testing, artificial limbs dynamics, space mechanics, and meteorology applications.

Similarly, at the junior level Fluid Mechanics course, the method employs a term research project in which students perform in-depth analysis, produce a technical report, and use various resources to learn new material independently in topics not directly discussed in class such as life sciences, physical sciences, astrophysics and geosciences, sports, wind effects on tall buildings, CFD, and other topics.

Another course included in this study is Propulsion Systems. Senior students are assigned to write essays on given topics, which encourage students to learn independently and gather and combine information on specific topics from different sources such as monographs, conference proceedings, and journal research papers. Students also develop skills using industrial software for the calculation and analysis of thermo-chemical parameters of the combustion of different fuels used in aircraft and rocket propulsion.

In the Senior Capstone Design course the assessment procedure focused on the synthesis and design of a complete mechanical engineering system, participation in team design and fabrication effort, and an oral presentation and team design report. For instance students have been involved in a design/research project where they performed experimental research on combustion of non-conventional bio-derived fuels for hybrid propellant rocket engines. Such a project requires self-learning of new material on two-phased combustion and flows, chemical thermodynamics, and analysis and research on current papers. As a result of this project, students are required to write a research report and submit and present the research paper at national or international research conferences. Thus they get valuable skills and develop competencies applicable in their future engineering practice and or graduate studies.

**Research Topics, or Open-Ended Design problems in Engineering Dynamics**

Engineering Dynamics is a sophomore level course at Central Connecticut State University (CCSU). The concepts of this course are fundamental for many subsequent courses like Machine Design, Modeling of Dynamic Systems, Fluid Mechanics, and many other courses. The wide spectrum of applications of these concepts in real-life engineering and daily life problems provides a rich source of lifelong learning problems. The pool of topics consisted of eleven research and open-ended problems. As shown (Figures 1 and 2), these problems covered a wide range of subjects including sports, entertainment, space mechanics, and meteorology to name a few.
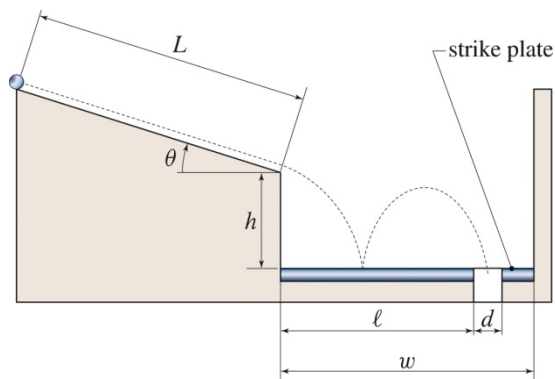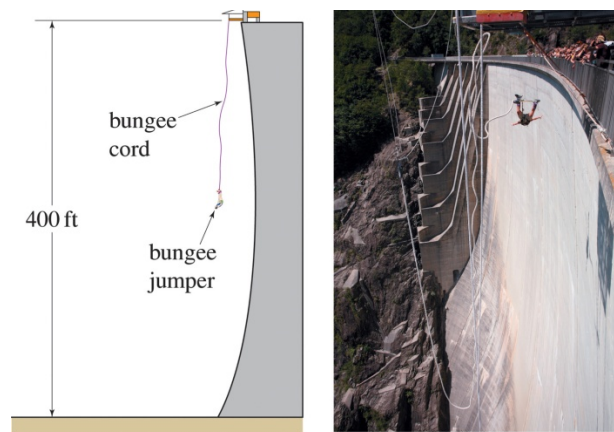
Figure 1: Sample dynamics problem -I[5]



Figure 2: Sample dynamics problem - II[5]

## Research Topics in Fluid Mechanics

In fluid mechanics course, the study was conducted over two consecutive years: 2010 and 2011. The pool of subjects covered a wide spectrum of engineering and non-engineering applications. Students were provided with twenty seven open-ended lifelong learning problems given at the end of each chapter in Munson's Fluid Mechanics textbook[6]. These problems involve topics that are not directly covered in traditional undergraduate course in fluid mechanics such as: Non-Newtonian Fluid; Lab on a Chip; Nano fluids; Liquid Jet Cutting Technology and Applications; and Swimming Efficiency and Improvement.

## Propulsion Systems: Project

Propulsion Systems is a senior level course that covers both aircraft and rocket propulsion and covers a wide area including combustion and fluid flows in propulsion and power generation systems, their theory, design and operation. It is almost impossible to cover in depth such a variety of topics during one-semester class. That is why writing essays pursue two goals: to learn material which is not covered directly or covered just briefly in the class, and cultivate research and analytical skills. Following topics are proposed for the research and essays writing: Hybrid Propellant Rocket Motors (HPRM); Solid Propellant Rocket Motors (SPRM); Electric Propulsion; Nuclear Rocket Engines: concepts, design, and application.

The propulsion project familiarizes senior students with industrial software such as Kintech Lab (Chemical Workbench)[7]. The software is a set of tools implementing multilevel modeling approach starting from first-principles structure calculations to the conceptual design of processes and devices. Kintech Lab software products are used in more than 150 organizations all over the world. The core part of Kintech Lab is Chemical Workbench - a fully integrated software tool aimed at the development and reduction of kinetic mechanisms, the conceptual design of physicochemical processes and technologies, and the performing of combustion analysis. Students learn and use Chemical Workbench for the calculation and analysis of parameters of combustion of aviation and rocket fuels. The culmination of the project is the Research Report which contains the results of the calculation of combustion temperatures, chemical composition, enthalpies, specific heats and other properties of combustion products and

analysis of the behavior of parameters versus fuel-to-oxidizer ratios and pressures. Below is the list of the individual assignments which are suggested to students:

Table 1: Propulsion Systems Individual Projects

| Student # | Design Variables | | | | | |
|---|---|---|---|---|---|---|
| | Fuel | Oxidizer | Initial temp. (K) | Pressure ($kN/m^2$) | Min. pressure ($kN/m^2$) | Max. pressure ($kN/m^2$) |
| 1 | $H_2$ | $O_2$ | 300 | 50000 | 1000 | 50000 |
| 2 | $H_2$ | $F_2$ | 300 | 50000 | 1000 | 50000 |
| 3 | $NH_3$ | $O_2$ | 300 | 50000 | 1000 | 50000 |
| 4 | $CH_4$ | $O_2$ | 300 | 50000 | 1000 | 50000 |
| 5 | $N_2H_4$ | $N_2O_4$ | 300 | 50000 | 1000 | 50000 |
| 6 | $H_2$ | $O_2$ | 500 | 10000 | 100 | 10000 |
| 7 | $H_2$ | $F_2$ | 500 | 10000 | 100 | 10000 |
| 8 | $NH_3$ | $O_2$ | 500 | 10000 | 100 | 10000 |
| 9 | $CH_4$ | $O_2$ | 500 | 10000 | 100 | 10000 |
| 10 | $N_2H_4$ | $N_2O_4$ | 500 | 10000 | 100 | 10000 |
| 11 | $H_2$ | $O_2$ | 400 | 25000 | 500 | 25000 |
| 12 | $H_2$ | $F_2$ | 400 | 25000 | 500 | 25000 |
| 13 | $NH_3$ | $O_2$ | 400 | 25000 | 500 | 25000 |
| 14 | $CH_4$ | $O_2$ | 400 | 25000 | 500 | 25000 |
| 15 | $N_2H_4$ | $N_2O_4$ | 400 | 25000 | 500 | 25000 |
| 16 | $H_2$ | $O_2$ | 250 | 1000 | 100 | 1000 |
| 17 | $H_2$ | $F_2$ | 250 | 1000 | 100 | 1000 |
| 18 | $NH_3$ | $O_2$ | 250 | 1000 | 100 | 1000 |
| 19 | $CH_4$ | $O_2$ | 250 | 1000 | 100 | 1000 |
| 20 | $N_2H_4$ | $N_2O_4$ | 250 | 1000 | 100 | 1000 |

**Senior Capstone Design Project**

The Hybrid Propellant Rocket Engine Senior Design/Research Project was started two years ago. The main goal of the project was to perform research on the combustion of non-conventional fuels such as paraffin, bee's wax, and lard.  Student teams designed and built a small-scale HPRE test fixture and instrumentation system for the study of the combustion of non-conventional fuels and the investigation of fuels regression rates. It is an ongoing project since each semester students continue to perform new research on the combustion of bio-derived fuels and obtain unique regression rates formulas which could be used in rocket industry. The multidisciplinary nature of the project provides engineering students with an excellent opportunity to apply their knowledge, skills, and experience from a variety of courses such as Propulsion Systems, Engineering Thermodynamics, Heat Transfer, Fluid Mechanics, Instrumentation, and Machine Design to real-life design and research. It is those characteristics that make this project a good lifelong learning assessment platform. Project research papers have been presented and published in the Proceedings of 50th and 51st AIAA Aerospace Sciences Meeting and Exhibits[8,9].

**Student Learning Outcomes and Performance Indicators**

According to ABET's literature[1]; student learning outcomes are defined as a broadly stated statements about general expectations that student are expected to acquire upon graduation.

These general statements are not measurable and can only be assessed using set of tools known as performance indicators. The performance indicators are defined as specific measurable statements that students are to achieve in order to satisfy a certain learning outcome.

Felder[3] divided lifelong learning outcome into two parts. The first part is the recognition of the need for lifelong learning which is, according to Bloom's taxonomy of educational objectives[10-12], governed by the attitudes and values that strongly influence the behavior of the learner and better known as the "affection domain". There are several levels of competency in this domain including, stimulating the students' interest in a certain area, students' response and attitude to this stimulus, and development and implementation of a systematic approach to learning. The second part is the ability to engage in lifelong learning which, according to Bloom's taxonomy of educational objectives[10-12], falls under the "cognitive domain". The mastery of this part is governed by several actions that, in general, focus on the students' ability to explore and generate new ideas, demonstrate comprehension, arrive at solutions, and, finally, judge the feasibility and value of these solutions or new ideas.

Based on the above, we have developed two performance indicators to assess the lifelong learning competency. These indicators were used in our ABET accreditation self-study report, and were accepted at all levels of the program's evaluation process:

1. Ability to recognize the attributes of a lifelong learner, the significance of lifelong learning, and to list sources for continuing education opportunities.
2. Ability to do in-depth analysis, produce quality work, pursue knowledge and use various resources to learn new material not taught in class independently.

The first performance indicator was assessed through a comprehensive survey, which focused on the students' appreciation of the importance, and recognition of the attributes of being a lifelong learner. The second performance indicator focused on the student's ability to independently investigate a research topic or solve an open-ended design problem. Obviously, at the undergraduate level, one should not expect cutting-edge research that substantially contributes to the knowledge base. Students did express their satisfaction and gratitude for doing something other than traditional homework, exams, and lab work. As an example, one mechanical engineering student wrote about the design of turbomachines rotors, "As an engineer, I found this subject the most fascinating of all other engineering studies. I enjoyed learning more about this project, and would consider turbomachinery as a concentration for a master degree in the future". After studying the wind flow effects on tall structures, a civil engineering student wrote, "This subject is ideal for my major, as I am a civil engineer. Since I am doing my internship in a structural engineering firm, and structural engineering is what I hope to do as a career once I graduate, wind pressure study on buildings are very important to me and my future success".

**Assessment Process – Performance Indicator I**

The first performance indicator focuses on the ability of students to recognize the attributes of a lifelong learner. This task was accomplished using a survey conducted after students have completed their research projects or solved an open-ended design problem. Completion of the survey was mandatory as no grade was issued for those who did not complete it. The short survey consisted of several questions that gave some reflections of the students' state of mind about understanding lifelong learning competency.

In the first question of the survey, students were asked to write their own definition of lifelong learning, the sample consisted of 86 students in four different classes at the sophomore, junior and senior levels. The responses were compared with the definition given by Candy[3] repeated here for convenience, "*equipping people with skills and competencies required to continue their own self-education beyond the end of formal schooling*".
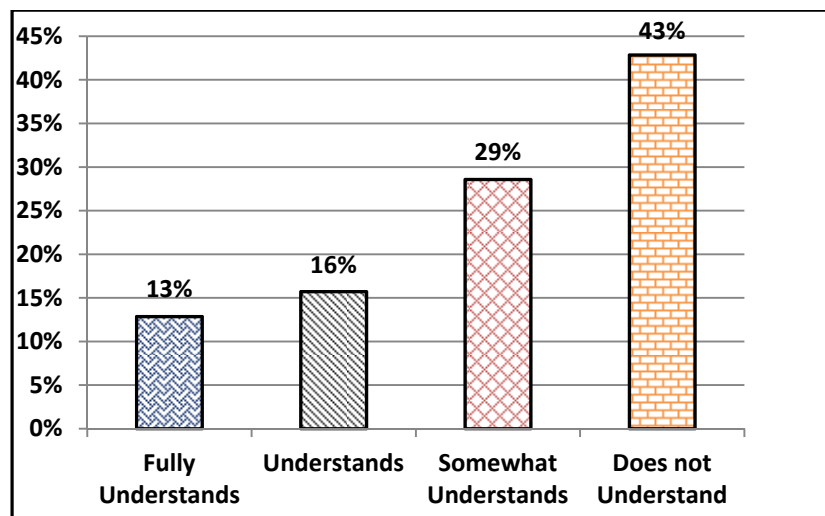


Figure 3: Students' own definition of lifelong learning compared to Candy's definition

Figure 3 illustrates students' understanding level of lifelong learning. As illustrated, students provided definition was compared were compared to Candy's definition and categorized into four levels understanding. Almost 30% of students show a good level of understanding of what lifelong learning is all about. The evaluation process of all the ABET Student Learning Outcomes a-k used in program self-study is as follows:

3.60 – 4.00   Exceeded

2.80 – 3.59   Met

2.00 – 2.79   Minimally Attained

1.00 – 1.99   Not Met

Based on this metric, we consider that the awareness level of the lifelong learning is minimally attained and measures should be taken to improve it. At the same time, we also believe that this initiative would enhance students' understanding level and help in providing them with a startup foundation.

The following are selected verbatim responses grouped according to their level of conformity with the categories illustrated in Figure 3:

I.   Fully understands (excellent definitions)
   a.   "Learning the process to learn"
   b.   "For a person to continually learn about new things throughout their lifetime"
   c.   "Being able to identify the need to continuously expand knowledge and adapt to ever evolving technologies."
II.   Understands (good definitions)

<ol type="a" start="1">
<li>"Being able to apply previously learned material and adapt it towards new problems."</li>
<li>"To me, lifelong learning means constantly learning new ideas and applying this new knowledge to my everyday life."</li>
<li>"Lifelong Learning means to learn as you go through life (personal experiences)."</li>
</ol>

<ol type="I" start="3">
<li>Somewhat understands (average definitions)
<ol type="a">
<li>"A project that has some effect on your life, whether it be understanding material better or something for your career"</li>
<li>"Learning something that will help you later in life not just learning something and using it for the test."</li>
<li>"Life Long Learning is learning something that will be useful for the rest of your life."</li>
</ol>
</li>
<li>Does not understand (insufficient definitions)
<ol type="a">
<li>"Problems that provide a sufficient knowledge for the student about a particular subject in Fluid Mechanics."</li>
<li>"Lifelong Learning is the idea of being taught something that will remain with you and help you throughout the rest of your career, academic or professional."</li>
<li>"My definition of lifelong learning is increasing my knowledge of the advancements in medical care and understanding where it originated."</li>
</ol>
</li>
</ol>

Figure 4 shows students' recognition of the attributes of a "lifelong learner". These attributes and skills are based on the "Foundations and Skills for Lifelong Learning Value Rubric"[13]. The study cited five skills that a lifelong learner must possess:

**Curiosity:** the ability and desire to conduct an exhaustive exploration of a certain topic or phenomena, or simply being inquisitive and yearn to learn.

**Initiative:** the ability to generate new ideas, to pursue opportunities, to learn new skills, and to come up with solution to emerging problems, all of which would definitely enrich the knowledge base.

**Independence:** the ability to learn how to learn independently outside the classroom environment

**Transfer:** the ability to build on previous own knowledge and experience as well as comprehension and applications and innovatively apply them to solve new problems.

**Reflection:** "Reviews prior learning (past experiences inside and outside of the classroom) in depth to reveal significantly changed perspectives about educational and life experiences, which provide foundation for expanded knowledge, growth, and maturity over time." [13]

The purpose of this survey question was to explore the mindset of students about the required skills, which would definitely enhance their awareness level, help them recognize and appreciate the importance of these attributes, and most importantly instilling the foundations of this important competency.
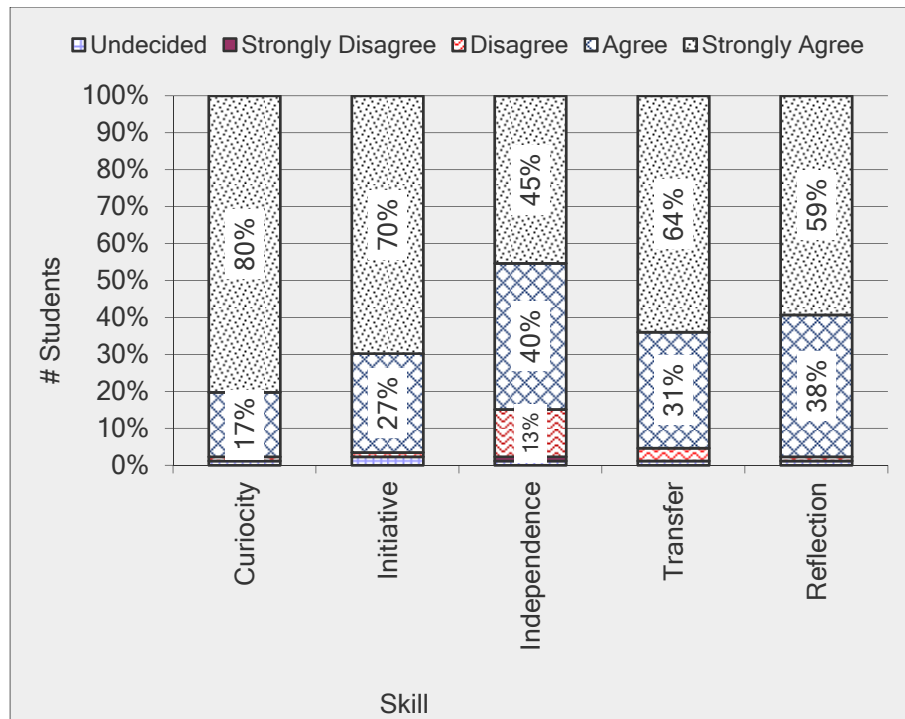
Figure 4: "In your opinion, what kinds of skills must a "Lifelong Learner" possess?"

Figure 5 shows the students' level of involvement in any research type projects during their academic career. It is obvious that the vast majority of students were not involved in any type of research-oriented projects prior to the lifelong learning initiative. Such an initiative, therefore, could be very valuable to students prior to their senior capstone project. It also highlights the need to instill the mentality of knowledge seeking outside the classroom early in the engineering program. For example, students in the freshmen level Introduction to Engineering course currently work on a team project developed from concepts presented in the class. Expanding the project to require the use of engineering principles not presented in class would necessitate students learning early in their academic career how to learn on their own. This can be clearly seen in verbatim response of a student in Engineering Dynamics about the definition of lifelong learning and the research experience:

"To me, lifelong learning is a skill, an acquired ability for one to continue their education in non-academic environments. ……. I knew that there were online journals available to the CCSU students from the FYE program, but since it wasn't a requirement for any assignment, I never utilized it. I'm happy now that I did because some of the information is of high quality and exactly what I was looking for. For example, trying to Google-search about bungee cords produced ……... All in all, now that I know how to and where to find new information, I plan to use it for the future, starting with a Matlab vision project, and even for fun when I want to learn something new. The project was a real-life application of dynamics where we were given a problem and combined studies in school with research through databases. This is a realistic outlook how lifelong learning will be in the future. Something will have to be designed that requires new knowledge building off of coursework studying."
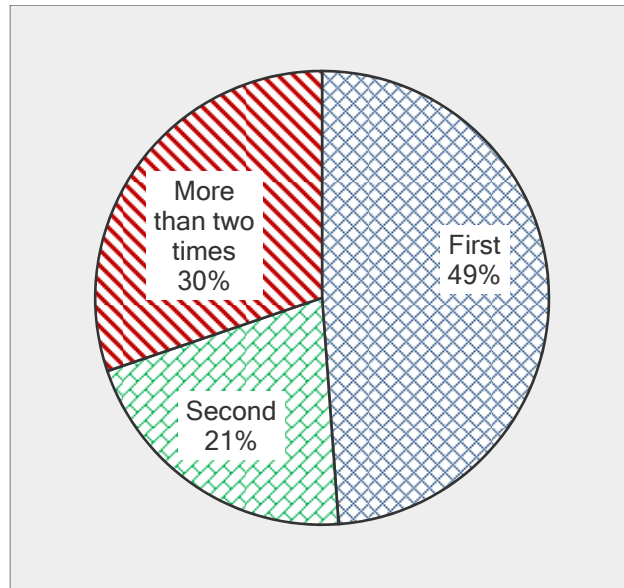
Figure 5: Frequency of students' involvement in research type assignments

Figure 6 depicts the students' rating of the lifelong learning experience. The vast majority of students (86 percent) found the experience positive and said it enhanced their ability to learn on their own, or solve open-ended problems with no obviously right answer. This would definitely enhance their critical thinking ability as they get exposed to real-world problems that they might face as a practicing engineers or researcher. This experience helped students, particularly those at the sophomore and junior levels, to realize that even when problems are not well-defined, they can be solved with different degrees of complexity depending on the available information. The available data can often be incomplete or is subjected to a variety of interpretations. These include problems that often need to be addressed repeatedly using trial-and-error, and/or optimization techniques and comparisons between simplified models and more complex real-world problems.
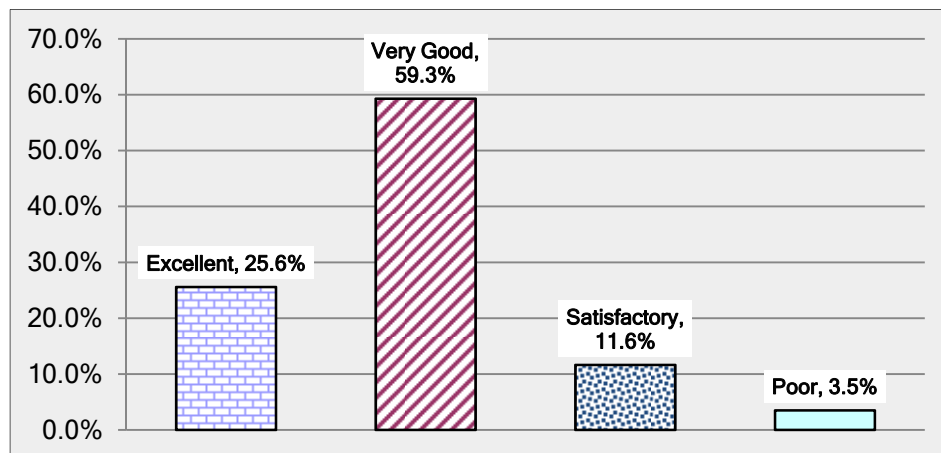


Figure 6: Rating of the lifelong learning experience

The final part of the survey was a set of seventeen questions to assess the effects of the "learn how to learn" skill as a result of completing the research project. Some of these questions are implicitly linked with the "VALUE" lifelong learning attributes. Table 2 and Figure 7 show the

set of questions and the survey results, respectively. The positive responses (significantly improved and improved) outweighed the negative responses (unchanged or unsure) by a ratio of three to one (3:1). The fact that the student sample included senior students who were involved in research type projects can be readily seen in these results. The sample included 22 seniors out of the 86 respondents. On average, 76% of the students reported either significantly improved or improved in the 17 skills listed in the questionnaire; this simply means that students do not believe they are well-prepared in most of these categories, and at the same time lead to the conclusion of the positive impact of this experience.

Table 2: Learning Trends Changes – Sample Size = 86

|  | **Survey Question Statement** |
|---|---|
| **Q1** | To realize the breadth and width of (Subject area: dynamics, fluid mechanics, propulsion systems) applications in different area. |
| **Q2** | To learn topics not taught in the classroom on my own. |
| **Q3** | To determine how much information is needed to answer a research focus question. |
| **Q4** | To know how to select appropriate keywords for searching Engineering Village, Compendex or other databases effectively. |
| **Q5** | To revise my selection of keywords to find information more efficiently. |
| **Q6** | To accurately summarize relationships between the main concepts discussed in an article. |
| **Q7** | To construct new concepts from my analysis of concepts discussed in an information source. |
| **Q8** | To identify contradictions, when they occur, in an information source. |
| **Q9** | To find and apply a review article to validate my understanding of a primary research article. |
| **Q10** | To make diagrams that accurately and clearly shows relationships among concepts. |
| **Q11** | To apply new and prior information to creating a written report on a specific issue. |
| **Q12** | To cite (acknowledge) all sources of information I include in my reports. |
| **Q13** | To understand journal articles written by scientists about their research experiments and theoretical findings. |
| **Q14** | To question the validity of information, including that from textbooks or teachers. |
| **Q15** | To distinguish fact from opinion, belief, and unsupported claims. |
| **Q16** | To explain in a clear manner a scientific concept or procedure to other people. |
| **Q17** | To evaluate my own writing assignments before turning them in for grading. |
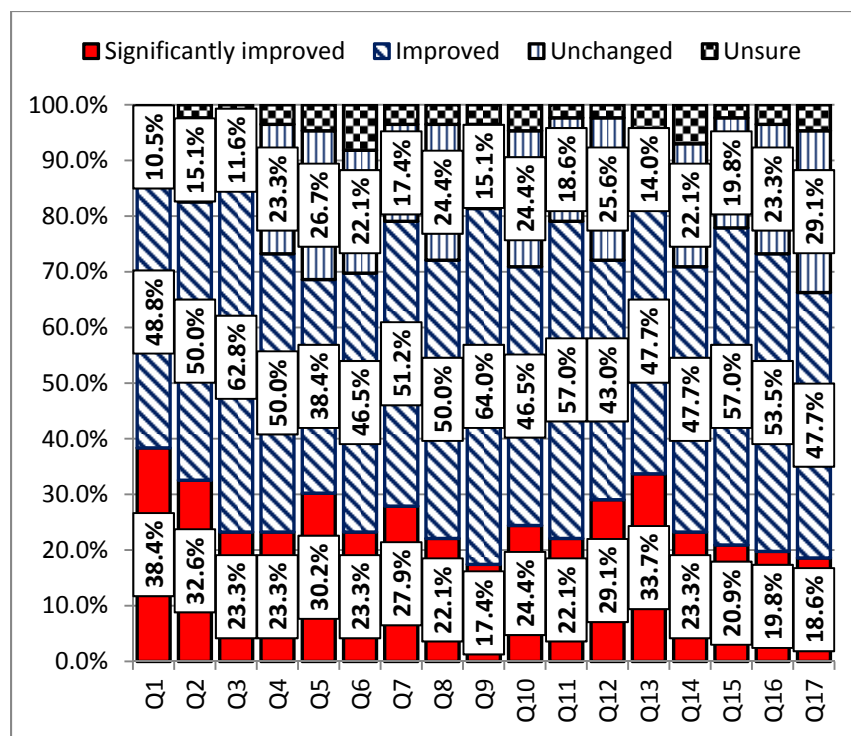
Figure 7: Impact on lifelong learning skills and tools

## Assessment Process – Performance Indicator II

The second performance indicator states that: The ability to do in-depth analysis, produce quality work, pursue knowledge and use various resources to learn new material not taught in class independently.

This indicator was assessed using technical report grading rubrics. These rubrics address presentation criteria, such as grammatical and paragraph usage and the use of citations, as well as content, such as abstract, objective of the project, results, analysis, and conclusions. On the positive side of the spectrum, the project exposed students to a set of vital skills necessary to be a successful graduate student or practicing engineer. These skills include but are not limited to: effective literature reviews from peer-reviewed published journal and conference proceedings, the use of electronic databases, and the interlibrary loan program. Additionally, students practiced validating information by distinguishing facts from opinions or unsupported assertions. Team work, and written communication skills were also practiced. On the other side of the spectrum, review of the written research reports revealed some shortcomings and concerns that need to be addressed. With the exception of the senior project, propulsion systems, and few reports in the fluid mechanics and dynamics, reports lacked proper analysis, synthesis, and logical conclusions and did not convey students' understanding of the problem. In fact, some reports were merely a pure literature review with no input and recommendations. Therefore, the second performance indicator was minimally attained.

## Conclusion

In this study, an assessment methodology of lifelong learning competency using engineering courses has been demonstrated. The main theme of the methodology is to engage students in

open-ended problems or research projects related to the subject area but not directly discussed in class. The research projects covered a wide spectrum of engineering and non-engineering real-life applications including but not limited to sports, medical, space, meteorology. Two performance indicators are used to assess the attainment level of the lifelong learning competency. The first is the ability of students to recognize and to understand the attributes of a lifelong learner, and the second is to implement these understandings in solving an open-ended problem or to conduct a research type project. The recognition part was based on the students' ability to identify the main attributes of a lifelong learner and was assessed using a survey, while the implementation part was measured based on the ability of the students to deliver quality work with proper analysis and self-input.

The sample size of eighty six students in this study is relatively small for any concrete statistical inferences. However, based on the students' feedback, interpretation of the survey results, analysis of the open ended questions, and evaluation of project reports, one can conclude that the methodology adopted in this study has been successfully implemented. In many aspects, the awareness level of the need for lifelong learning, and what it takes to be a lifelong learner have been positively impacted students involved in this study. In this information age, finding relevant information is not a challenging task using Google or other search engines in the World Wide Web, on the contrary, the abundance of information and source reliability pose the real challenge. The need to distinguish between facts and opinion has been highly emphasized in the research report writing instructions. Students were made aware of the fact that arguments, no matter how persuasive, are of little value if based on opinions that may not be true or reliable. Students who participated in this study are now aware of the existence of other, although traditional, but more reliable sources than the world wide web, such as journals and conference proceedings. As illustrated in the data, it was the first time for most of students to be involved in such an experience. Therefore, one should not expect an original research or new findings out of this endeavor at this level of education. Despite the aforementioned fact, the experience is very beneficial and effective way to know how to systematically research or investigate a given open-ended problem. Students' reports were graded based on content, quality of the presentation, and use of assumptions and justifications. The logical and scientific explanation for findings, and recommendation of specific changes that would improve the investigation were also considered.

Generally, the adopted procedure outlined in this paper has been successfully implemented; students' feedback was very positive and encourages us to continue using this assessment tool. Several other competencies can also be effectively assessed such as team work, and communication skills. We also expect that the technical content of the reports will improve as students mature in the academic program. The fact that several senior design projects have been published and presented in international conference asserts this observation.

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