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Multi-Approach Evaluation of Entrepreneurial Capstone Course

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Abstract

This paper presents and analyzes a nontraditional design and practice of an interdisciplinary entrepreneurial senior project course in Engineering Technology Education. The paper will study and discuss how the real life approach to the delivery of the course creates an industrial-like environment for the different students' teams to work on their distinct projects and evaluate other student's projects. The paper will demonstrate how the search for intellectual property (as a part of the design) is used to develop and enhance the fostering and building the entrepreneurial mindset and experience. The paper introduces and analyzes an academic model that allows each student to participate in a process that embraces the importance of documenting and validating product ideas using real-world techniques and tools. The student's entrepreneurial learning experience is well grounded and begins with a patent search using the web-based tool of the United States Patent Trademark Office (USPTO).

Statistical analysis of gathered data will reveal the value of understanding this process and a body of applied engineering knowledge that is available in the quest to obtain a patent. Objectives of the course are well defined and discussed with students, which will lead to an effective assessment tools of the experiences and outcomes. The design copies the real industrial world practice by having students present their projects plans, work progress and final demonstrable products to their peers and an Industrial Advisory Board (acting as the voice of customers). By design of the course, each team will be formed around a product. The constraints and challenges of developing a product, engineering it and preparing it to be marketed will be presented in this paper. Entrepreneurial experiences and real-world practice are integral parts of the learning process.

Real-world entrepreneurial mind set is linked to each student team as they start their product idea and move it through the validation process. The patent search is an excellent broadening of the mind; it might lead to discover work that is close, overlap or even is replica of the team preliminary product idea. In these cases, they cannot continue with their preliminary product idea and must become innovative. This practice illustrates a valuable lesson, which integrates with other components of the entrepreneurial learning experience. Learning how to manage failure is a key ingredient of building the entrepreneurial mindset. Students from three different Engineering majors work together in this course. The teams have been interviewed and their individual learning experiences will be analyzed in this paper. Student perspective and their assessment is an important tool used to adjust and continuously improve the design of the course and its links to the engineering education curriculum.

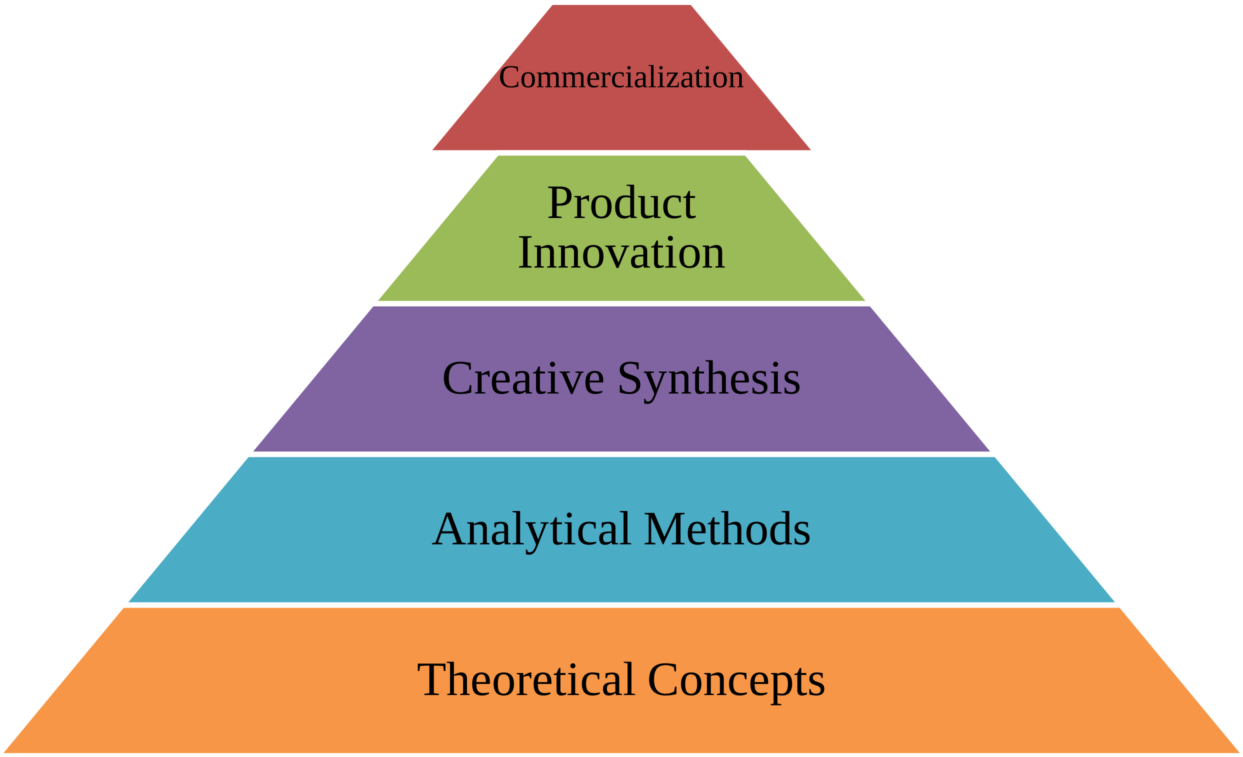
1.0 Course Design

The senior project course of the Engineering Technology Department represents the highlight of the curriculum since 1986. It provides an excellent example of translating LTU philosophy "Theory and Practice" into a curriculum. Students apply academic knowledge and skills acquired through different courses in this creative and real professional exercise. An important requirement for this senior project course was to have it taught by a professor that had an entrepreneurial experience and mindset to develop the course. Current course design and structure evolved over twenty years of teaching it by the same entrepreneur instructor that developed and kept improving it. Because the instructor has about 30 patents, his experience helped design the course, develop contents and delivery methods as follows.
The design encompasses:

i. Theoretical Concepts, which includes historical review.
ii. Analytical Methods, using the math and science concepts accumulated through the degree program.
iii. Creative Synthesis, including brain storming and collective thinking sessions, and patent search to think up new ideas.
iv. Product Innovation, where students will practice the actual making of new products.

v. Commercialization, were students will utilize the entrepreneurial mindset to look for commercial opportunities.

The following chart represents the pyramid structure of the design.



Delivery method in this course is unique; the professor acts as the CEO of an international corporation and the students are employees from different operating divisions that have technical or business issues. They are brought together to develop new or innovative products to make their divisions sustainable and profitable. It is very important to establish the entrepreneurial mindset by the CEO/professor (CEO/P) that fosters teamwork with a free spirit of brainstorming. This structure provides real-world situations as in industry. The CEO/P plays the role of a mentor who provides encouragement and instills confidence that the employees/students (E/S) can deliver the product on time, while meeting the project objectives.[4]

Students brainstorm as a group of employees over several meetings and their ideas are recorded. Ideas related to experiences, hobbies, family interactions, work experiences (not specific to their employer) are brought up for discussion.

The product ideas are scrutinized by the CEO/P to eliminate ones that could not be completed in the allocated time frame, are outside of the scope of technical feasibility, or requires resources beyond their financial means. The E/S are asked to review these product ideas and to use their interest and skills “heart and head” to vote their first and second choice. This voting selection does not have to include their E/S own product ideas. The voting is open and verbal with the entire E/S involved in the process, and is completed in a short period of time.

To determine the strengths and academic specialties of the teams, the members interview each other. The outcome of this determines their position/title in the organization chart of their operating division under CEO/P Enterprises. Examples of this could be vice president of engineering, manufacturing, and marketing. The team establishes a divisional name, logo, mission, quality statements, and preliminary product abstract. The next step is to develop a project timeline, using Microsoft Project ™, from a list of tasks required to complete the product.

A lecture is given on all forms of Intellectual Property (IP) and specifically utility patents. Using this information, a preliminary IP patent search is performed using the United States Patent and Trademark Office (USPTO) website.[6]

Based on information obtained from this search, the product idea may be improved, modified, or abandoned. A patent attorney guest lecturer reinforces their experiences and findings after their IP patent search.

The product abstract, used for the market survey, could be edited using the patent search information. The market research questionnaire, based on previous experience, should be no more than 10 multiple-choice questions. This survey should consist of questions pertaining to the demographics of potential customers, selection of product features and price points associated with it. Also, the questions should ask if the customer will buy this product, and if so how much are they willing to pay for it. Analysis is performed on the data consisting of numerical and graphical presentation. The information from this analysis will be used for product features, manufacturing requirements and advertising penetration.

Product specifications should be based on requirements learned from the IP patent search and the market survey. The design, engineering/CAD drawings, prototyping, bread boarding, and preliminary testing should be completed to meet the basic product specifications. If this is not met, then a redesign may be required. If the preliminary design is proven functional, then final material procurement, construction, packaging, and testing should be finished. Next, product documentation, bill of material, cost and break even analysis, should be completed. Production requirements and inventory turnover are determined by the results from market size and customer survey. If the target ROI (Return on Investment) is not met, several techniques should be employed, such as increasing advertising for improved market penetration, improving manufacturing efficiency (off shore versus local), and improving product features or application.

Several oral presentations and work outside of the classroom are required from the teams throughout the course. A video documentation is recorded of the final presentation and product demonstration by each team. The E/S must prove and demonstrate their product to the CEO/professor, their peers, and the Engineering Technology Industrial Advisory Board. A project book is assembled during the total development cycle and contains all documentation in printed and electronic format. The team project book, which will be submitted at the end of the term, contains the following:

1. Division name, logo or trade mark, etc.
2. Table of organization with each member's title and responsibilities.
3. Autobiography of each member of the team.
4. Brainstorming notes, sketches, product ideas, etc.
5. Product/project timing using MS Project ™
6. Mission statement
7. Quality statement
8. Product name and logo, including a description or abstract.
9. Patent search, class, sub classes, and copies of previous art work, discussion of IP patent search outcomes.
10. Market research of the product. This includes the survey questionnaire, customer survey results, product trade-off analysis, measurements and conclusions.
11. Product engineering includes design, CAD drawings, calculations, testing, data analysis, software, sustainability analysis, packaging, recyclability, bill of materials and parts cost.
12. Manufacturing includes cost, quantity, quality control measures, in-house, farm-out, etc.
13. Financial includes break-even-analysis, inventory turns, and a 15% ROI within a five-year start up.
14. Marketing, sales distribution, advertising
15. Product manuals, etc.
16. Miscellaneous

The course design includes a set of measurable objectives describing the skills and competencies that students should acquire and could be used to assess the learning experience. These objectives are:

1. Participate actively in a product development cycle from brainstorming to a deliverable product
2. Present work progress and product professionally
3. Document product process and materials effectively
4. Perform successful product research, market survey and production analysis

These objectives are assessed directly by the instructor and indirectly by the students; the assessment process provides data for closing loops and improving the course. In general, the design of this course makes it innovative in engineering education. It combines methods used in business and engineering to create marketable products in an environment that is representative of today's industry.

3.0 Students Outcome Evaluation

The Department of Engineering Technology at LTU adopted ABET student's outcomes and mapped them to the Department Educational Objectives. The evaluation of this course has multiple approaches and utilizes several assessment tools that are used in the department for all courses and those which are used uniquely for the senior projects. This multiple approach method is comprehensive and it will capture any inconsistency in the process.

3.1 Direct and Indirect Course Learning Objectives Achievement

This approach to evaluation is practiced for all courses in the department and serves our purpose in this paper because it provides instructor and students data to evaluate the same learning objectives. Hence it can capture any inconsistency in the evaluation.

Direct Assessment Tool:

This tool is prepared by the instructor of the course. The instructors set up the mastery bar for each learning objective using a statistical indicator, which is normally a percentage. The objectives are directly tested through student's evaluation tools such as exams, projects and homework. Each instructor is to calculate the average performance of the class towards each objective and record the data.

Indirect Assessment tools:

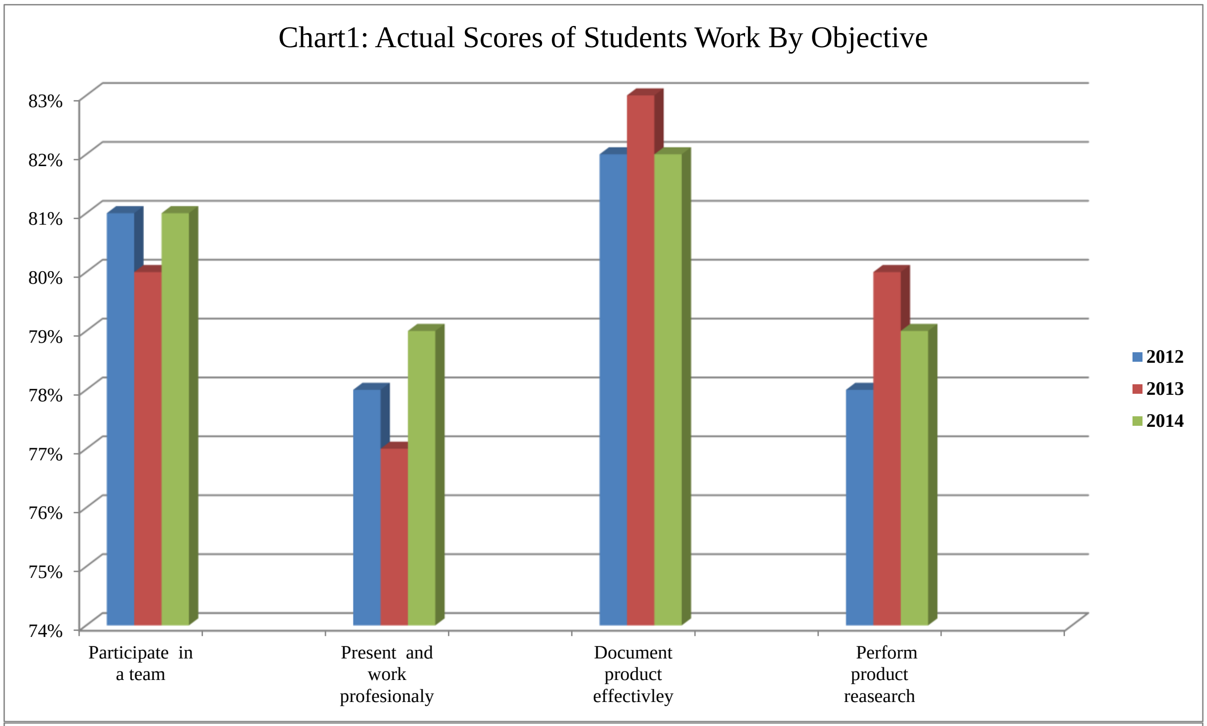
Students in the course are asked to complete a questionnaire as they are about to finish the semester. The questionnaire includes direct questions about the Course Learning Objectives and how they evaluate the achieving of those objectives. The students will be asked to rank the achievement of all Course Learning Objectives.

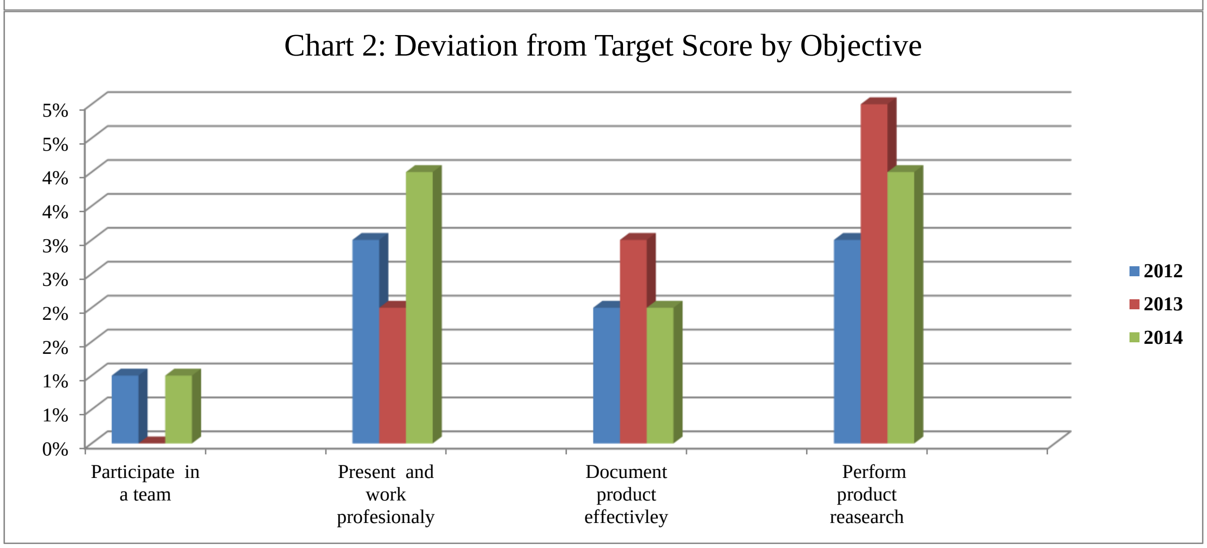
The assessment data provide evidence of successful achieving of the Course Learning Objectives if both assessment methods provide consistent conclusion. Assessment data gathered for the senior project course are presented below:

Table 1: Senior Project Direct Assessment result 2010-2012

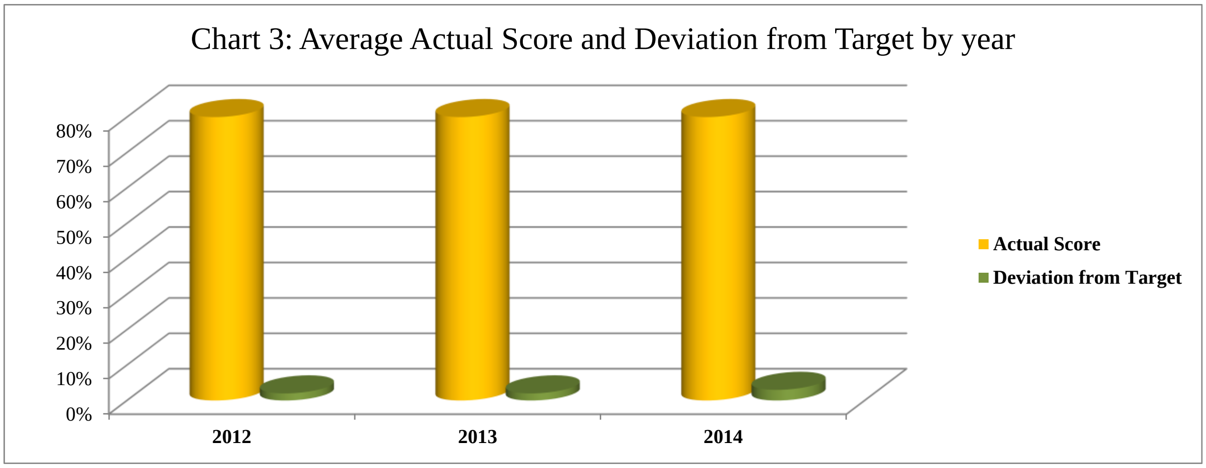
	2012		2013		2014	
Course learning objectives	Actual average Score	Deviation from Target	Actual average Score	Deviation from Target	Actual average Score	Deviation from Target
Participate Actively in a team	81%	1%	80%	0%	81%	1%
Present product and work profesionaly	78%	3%	77%	2%	79%	4%
Document product process and materials effectivley	82%	2%	83%	3%	82%	2%
Perform successful product reasearch	78%	3%	80%	5%	79%	4%
Mean	80%	2%	80%	2%	80%	3%

Table 1 above is a summary of the direct assessment process that represents three semesters from three different academic years. The actual score was produced through what the instructor has gathered during the semester. Comparing the actual score per objective with the target score achievement that was preset for each objective, the deviation will be calculated. Since the deviations are all positive, we conclude that the target has been met and exceeded with different level for different objective. The mean of the deviation, which is an indication that the target for the whole course was met, was a reflection of a successful achievement of educational objectives. The charts below provide a comparative look between the actual scores and the deviation from target over the three years.





It is clear from Charts 1 and 2 that there is a matching pattern between the scores and the deviation over the years between the four Course Learning Objectives. The conclusion of the instructor and the department was that the direct assessment provides solid evidence of achieving the course goals. We can notice from the Chart 3 below that the actual average score for all the Course Learning Objectives and the deviation from target were almost identical through 2012-2014. This is shown in the chart below:

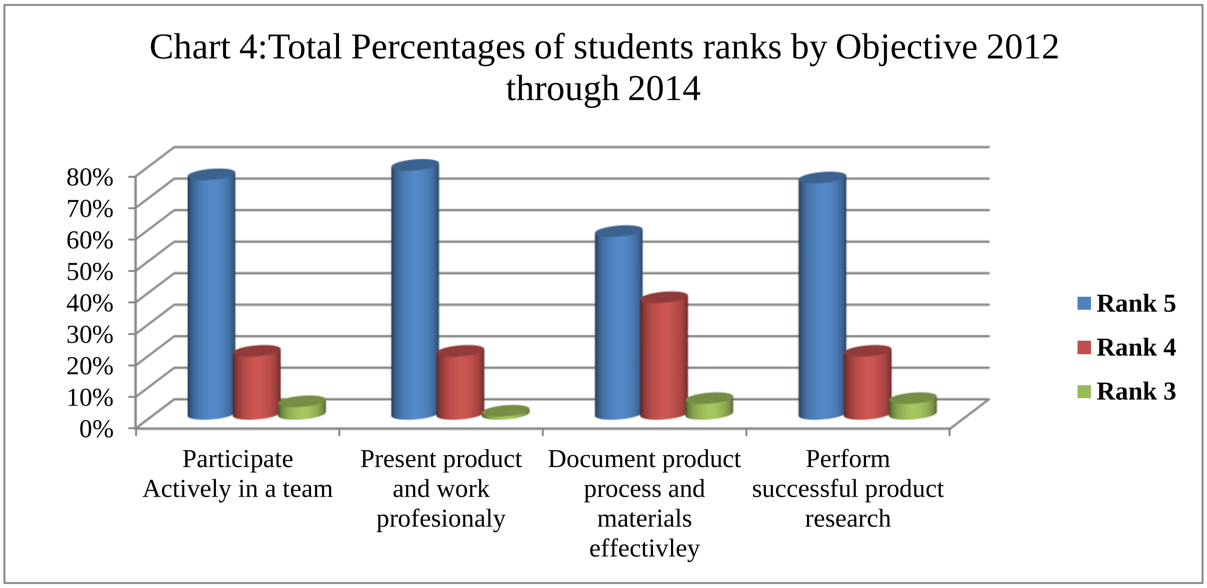


The analysis of the direct assessment should be performed alongside the indirect assessment to test for consistency of the indicators and conclusion. The tables and charts below represent the data collected through the indirect assessment process:

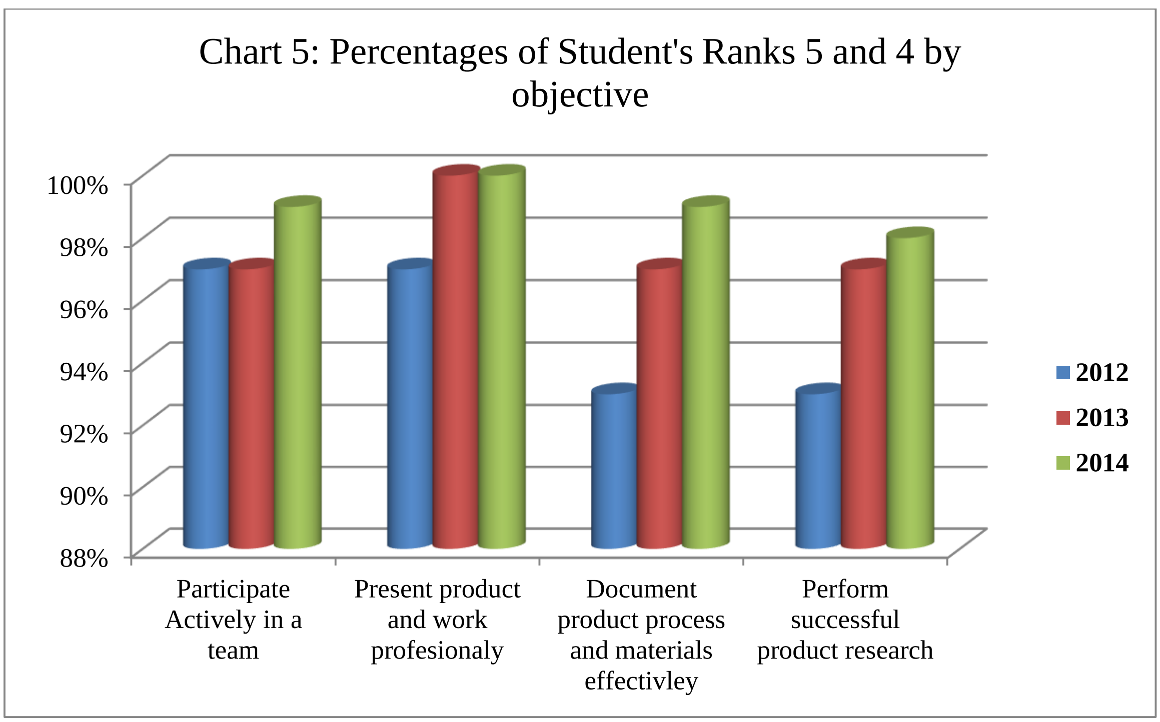
Table 2: Total numbers of ranks 5, 4 and 3 by Objectives

Course learning objectives	Rank 5 Perfectly Met			Rank 4 Very Well Met			Rank 3 Reasonably Met		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Participate Actively in a team	22	25	15	6	6	4	1	1	1
Present product and work profesionaly	23	25	16	5	7	4	1		
Document product process and materials effectivley	17	18	12	10	13	7	2	1	1
Perform successful product research	22	24	15	5	7	4	2	1	1
Total	84	92	58	26	33	19	6	3	3

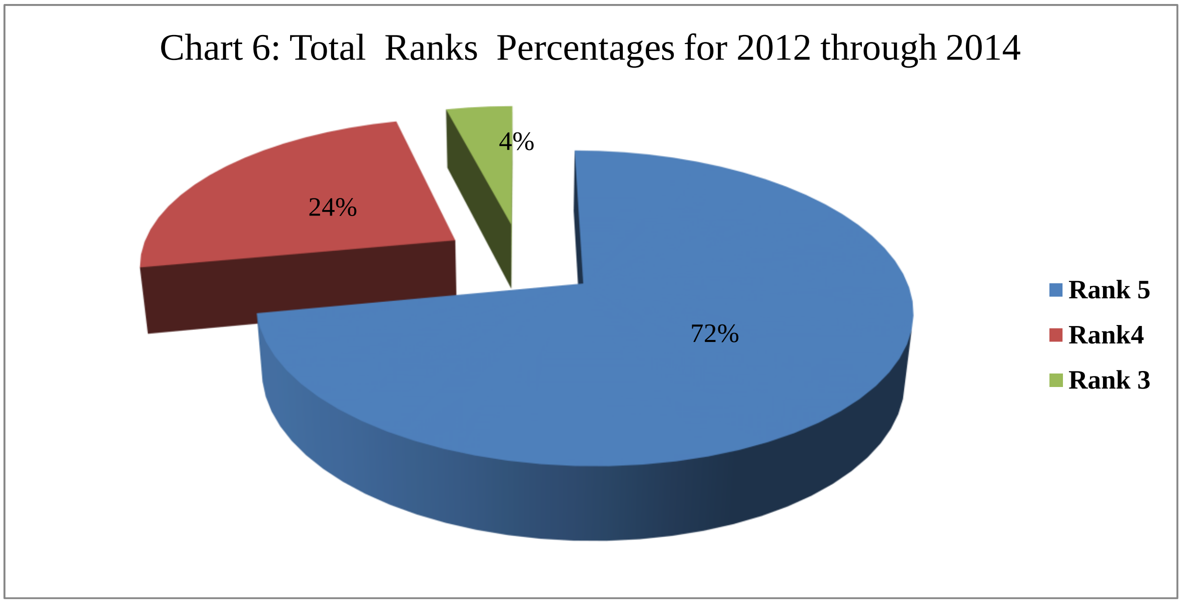
Although the ranks are from one to five (five being the best), the actual ranking by students for the achievement of all the Course Learning Objectives did not show any student ranking any objective with less than three, which means that the objective was reasonably met from the student point of view. Chart 4 represents the percentages of student's ranks for each objective through the three assessment years:



It looks like the documentation objective was not ranked as highly as the other three objectives were. The chart does provide a positive picture about how students think of their achievement of the course objectives. The next chart 5 agrees with the conclusion, since we can notice the percentages of students ranking objective four with 4 and five.



The general trend is that the ranking of all the objectives is improving over the years. This is not only an indication that the course is getting better, but it might be that students are more focused on Course Learning Objectives, since this delivery method is being applied in all the courses in the department. Chart 6 provides evidence of consistency of the indirect assessment of the senior project course with the indirect method of assessment. The percentage of students ranking the achievement of the course objectives as perfectly met (Rank 5) and very well met (Rank 4) where 72 and 24, respectively totaling 96% of the students as it is pictured in Chart 6:



3.2 Students' Entrepreneurial Experience Evaluation

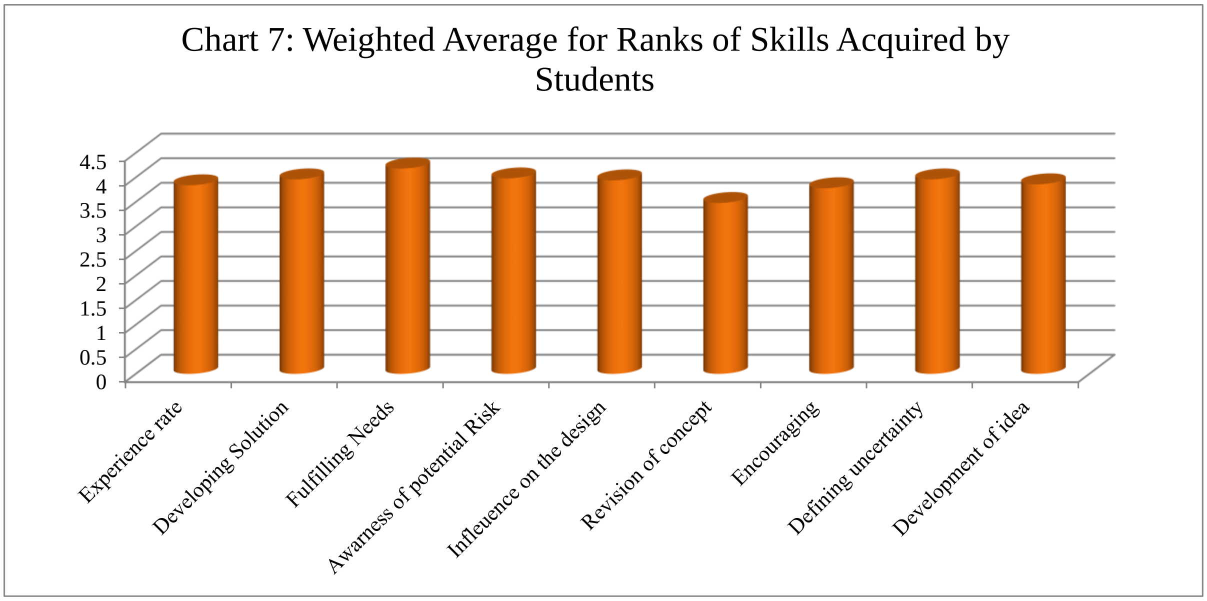
To evaluate the contribution of the course to entrepreneurial mindset of students, a questionnaire was developed and was given to 68 students over the years who took TIE4115 Senior Projects. The analysis of the data collected provides sufficient evidence to support the idea that the course contents and the teaching approach used to deliver the material has resulted in learning experiences that fosters entrepreneurial thinking. "An opportunity with no or very low potential can an enormously big opportunity".

The value of participating in the IP patent search process directly pertains to developing and creating an understanding and awareness of the entrepreneurial mindset. The questionnaire included two sets of questions that are directly related to the entrepreneurial sets of skills and lessons learned. First set included nine questions, where students were asked to rank each of the nine entrepreneurial skills acquired through the course. The data are summarized in the following Table 3:

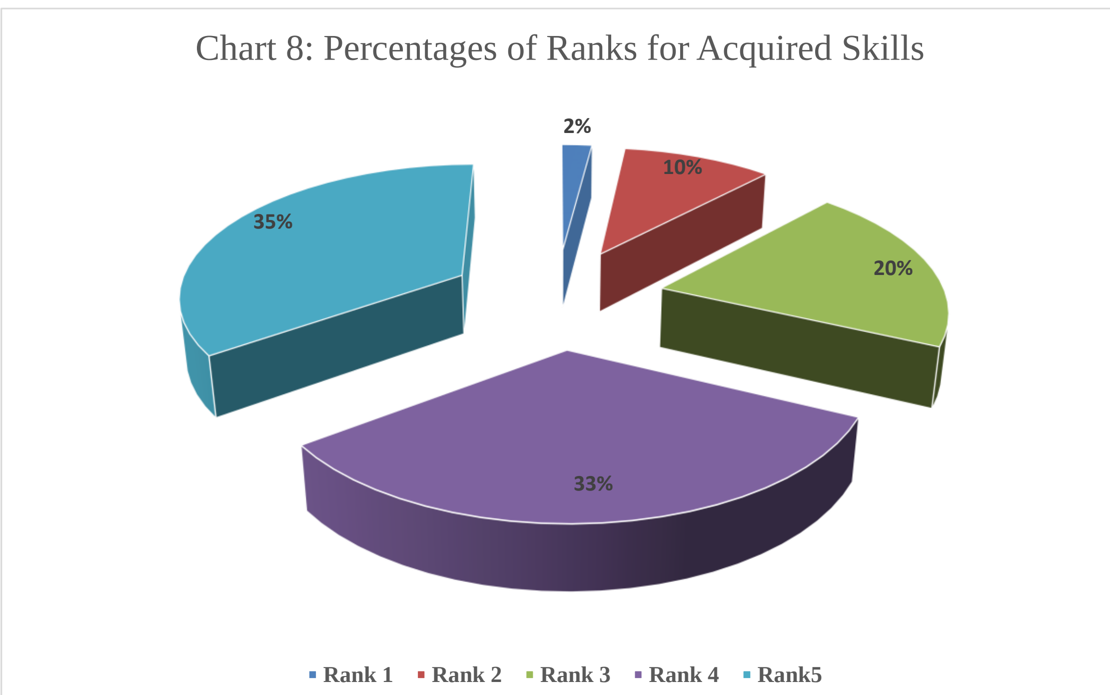
Table 3: Responses of 68 students on skilled acquired questions distributed by rank

Question	Topic	Weighte Average	Rank				
			1	2	3	4	5
1	Experience rate	3.84	2	6	10	12	20
2	Developing Solution	3.96	1	6	9	12	22
3	Fulfilling Needs	4.18	1	2	6	19	22
4	Raise awarness of potential Risk	3.98	1	6	8	13	22
5	Infleuence on the design	3.94	2	5	7	16	20
6	Caused the revision of concept	3.48	2	13	7	15	13
7	Encouraging	3.78		4	14	21	11
8	Effectivness of defining uncertainty	3.96		2	14	18	16
9	Incresed successful development of idea	3.86		3	14	20	13
	Ranking weights	3.89	9	47	89	146	159

We can read in Table 3 that the majority of students did rank the acquired skills highly. The overall average for all the nine skills was 3.89, which is reasonably high. The weight of rank one was 9 and 47 for rank 2 versus 159 for rank 5 and 146 for rank 4 with the middle rank had a weight of 89. These data are displayed in Chart 7 below and provides a snapshot supporting the conclusion from the data.



The second set of questions are about lessons learned by each student in a team. This represents the feedback received after the team that has conducted an IP (Intellectual Property) search. These questions focused on the characteristics of the entrepreneurial mindset. Data in Table 4 demonstrates the value of this learning process. A look at the data from Table 3 that are represented in the chart below, suggests that 68% of ranks were for the highest two ranks 4 and five, whereas only 12% were in favor of the low ranks of 1 and 2. The 20% for rank 3 is also relatively high and the focusing should be on reducing it in favor of the ranks 4 and 5.

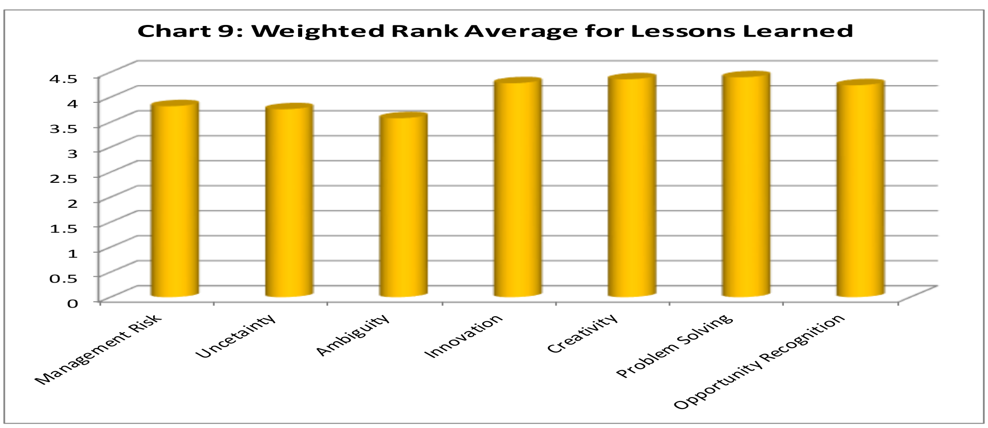


The second set included seven questions about lessons learned. These questions are also related to the quality of entrepreneurs, like the risk management and innovation among other questions. The data from the 68 questionnaires are summarized in Table 4 along with the weighted averages and the overall average for the lessons learned. Similarity of student's responses between the first and the second set of questions is noticed, here again the student's appreciation of the lessons they have learned is demonstrated through the high ranking that they provided. Problem solving, creativity and innovation lessons had the highest weighted averages among all proposed seven lessons, while the lowest, but certainly not low was ambiguity. The general average of 4.06 indicates a very good level of learning.

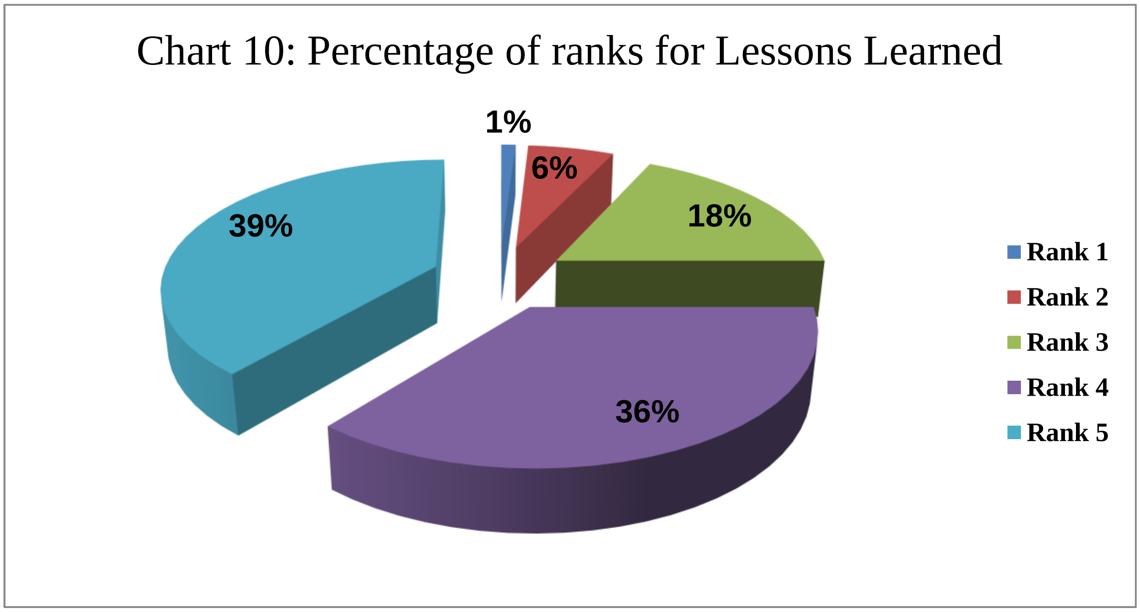
Table 4: Responses of 68 students on lessons learned questions distributed by rank

		Rank				
Lesson Learned from Senior project team	Average	1	2	3	4	5
Management Risk	3.82		6	12	17	15
Uncetainty	3.76		3	15	23	9
Ambiguity	3.58	2	4	18	15	11
Innovation	4.28		3	4	19	24
Creativity	4.36		3	3	17	27
Problem Solving	4.4	1	1	3	17	28
Opportunity Recognition	4.24		2	7	18	23
Ranking weights	4.06	3	22	62	126	137

A more clear picture is presented in Chart 9 showing how the ambiguity achieved the absolute lowest weighted average and the only one below 3.5. Results revealed that student provided lower ranking of the management of risk, uncertainty and ambiguity in comparison with other lessons learned. One reason could be that these lessons do not directly affect the team work and progress that they are making during the course.



The percentage of students ranking 4 and 5 to the lessons learned was higher than that of the skills acquired. As is presented in chart 10, this percentage is 75%. The rank 3 here again is somewhat higher than what the instructor would like to see.



4.0 Conclusions

The project design course offers unique opportunities for students in engineering disciplines to develop challenging skills, and be prepared to start their careers in a highly competitive and global market. Curriculums in programs are being reviewed, upgraded and enhanced continuously to meet todays and future requirements of engineering careers. Traditional approach to this course will not achieve the goal. The design introduced, discussed and analyzed in this paper has proven successful over the years. The data presented supported the hypothesis of a successful course that could be described as the highlight of the program curriculum, the students will apply most of the knowledge areas that they have learned and allow them to work in the closest environment to the real-world scenarios.

We recommend that:

- Other departments should try some similar nontraditional approaches to these courses and share the feedback.
- Industry should be encouraged through the ASEE to be more involved in sponsoring senior projects and to add more pressure and responsibility to the teams working in these projects. This will help simulate the actual work environment in industry.
- In the experience that this paper presented, students in the course and eventually in the teams come from three different programs of the Engineering Technology department (Engineering Technology, Construction Engineering Technology and Audio Engineering Technology). It is highly beneficial to have multi-engineering disciplines in the senior project experience. In real-industrial world, mechanical engineers, technologists, electrical engineers, biomedical engineers all might work together in one team. This will better prepare the students for their careers.

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