Columbia International Publishing
Journal of Continuing Education and Professional Development
(2013) Vol. 1 No. 1 pp. 14-26
doi:10.7726/jcepd.2013.1001-1
Research Article

Integrated Multidisciplinary Engineering Early Design Project: Approach and Reflections

Fadi A. Ghaith[1*], Mutasim Nour[1], Sarim Al-Zubaidi[2], Nidhal Abdulaziz[3], and Mounif Abdulla[1]

Received 24 June 2013; Published online 3 August 2013

Abstract

This paper presents the implementation of vertical and horizontal integration of engineering education in an early design project. In this project, multi discipline first year engineering students were asked to design, build and test a device which can generate electricity from green energy sources. The project is embedded in the undergraduate mechanical engineering science course which is a core course for mechanical, automotive, engineering and management and civil engineering students. The structure of the project involves horizontally four first year students from different engineering departments and vertically a fourth year student as a group leader. The primary aims of this study were to investigate the applicability, efficiency and reflections of the early design project in developing the design skills and enhancing the student learning experience. Quantitative and qualitative surveys were conducted and analyzed to capture the reflections of the students and the project supervisors involved. The obtained results showed that the proposed early design project contributed to the personal gain of knowledge of students, improved their design skills and engaged them in constructive multi-disciplinary collaborative work. Also it demonstrated the importance of this design project in attaining the learning from practice and developing self-learning and presentation skills.

Keywords: Early Multidisciplinary Design Project; Vertical and Horizontal Integration; Reflections

1. Introduction

The school of Engineering and Physical Sciences (EPS) at Heriot-Watt University, Dubai Campus has offered since 2006 many programs in engineering studies with emphasis on both the acquisition of knowledge and the development of engineering skills. Hence, team work, communications, creative thinking and efficient projects management are assessed and considered in the curriculum, and cultivated through active learning methodologies. Different approaches and strategies have been developed to achieve and retain the involvement of the professors and students in effective

* Corresponding e-mail: f.ghaith @hw.ac.uk
1* School of Engineering and Physical Sciences, Heriot-Watt University, Dubai , UAE
2 School of Engineering, Nazarbayev University, Astana 010008, Republic of Kazakhstan
3 School of Computer Science &Engineering, University of Wollongong, Dubai, UAE

learning, team-oriented activities, such as the first year design project. This early design project involved a group of students who were put to work together to attain a common goal. A typical model for this design project is "design-build-test" model. In this model, the students are expected to come with innovative designs, followed by building and testing their prototypes. Also the students are expected to provide simple analysis to predict the influence of changing design parameters on the performance of their proposed design model. It is well known that design is the core activity of engineering (Simon, 1996). Also it is widely agreed that engineering programs should graduate engineers who have the capability to produce proper designs and solutions to meet the industrial demands and social needs (Sheppard, 2003). On the other hand, and over the last five decades, engineering curricula have been based mainly on "engineering science model", in which engineering design is taught only after a solid basis in science and mathematics (Clive et al., 2005). This model has a major pedagogical weakness as it keeps the first- year students far away from any practical engineering applications (Agogino et al., 1992 and Pavelich et al., 1995). Therefore; many researchers pointed the importance of engaging the students with some engineering design works at the early stage of their education, in which they can enjoy the experience of learning the basic elements of design process by involving them with real design projects (Dym 1994 & 2003).

The tutorials questions at undergraduate education for the first year of an engineering program are normally directed towards solving exercises to a unique answer. Those are often having simplified assumptions embedded in them and occasionally students will be provided with a solution hint or hints. Similarly individual or group projects are normally conducted to demonstrate knowledge of principles or procedure that is specifically stated in the course outline. The proposed first year design project can be classified under the category of Project Based Learning (PBL) as it satisfies the definition of PBL reported by Milentijevic et al. (2008) in which they stated that "*PBL is a constructivist pedagogy that intends to bring about deep learning by allowing learners to use an inquiry based approach to engage with issues and questions that are rich, real and relevant to the topic being studied*". In line with Barron definition of PBL (Barron, 1998), this project is designed to be used for requiring the students to investigate thoroughly in order to attain better understanding. Thompson and Beak (2007) demonstrated the importance of such projects by providing the students with a comprehensive approach to linking the concepts and realities and engages students in a collaborative learning activity that challenges them as both individuals and group members. Rhodes and Garrick (2003) highlighted in their study the influence of PBL in bridging the theory with practical activities and they considered it as essential step to enter the real world and understanding the actual job conditions. The role of collaboration in PBL appeared apparently by considering the importance of teamwork in overcoming the complexity, multidisciplinary and self-dependency on organizing their work without any detailed guidance. According to Thompson and Peak (2007), collaborative learning is a fundamental pedagogical practise which enhances the understanding of the students, and putting them in the correct track in developing their personality and skills. This early design project was designed to meet the components of the Integrated Design Project (Giralt et al., 2000). The vertical integration is achieved by enrolling one 4th year engineering student in each group, which implies an indirect way of integrating knowledge and processes.

One of the main objectives of this study is to measure the reflections of the participants about the proposed early design project. Reflection is considered as one of the most efficient and productive tools for developing teaching practice. By referring to the literature, one of the main originators of the concept of reflection is found to be Dewey (1933). Moreover, many researchers have used the terms "reflection" and "critical reflection" in the context to describe the most recent techniques proposed for developing teacher education. Many definitions for reflection have been posted in the literature, while the most comprehensive and specific definition was stated by Moon (1999) in which he wrote: "*Reflection is a form of mental processing – like a form of thinking that we use to fulfill a purpose or to achieve some anticipated outcome. It is applied to relatively complicated or unstructured ideas for which there is not an obvious solution and is largely based on the further processing of knowledge and understanding and possibly emotions that we already possess*". Most of the recent literature is tackling the problem of how we can implement reflective practice to enhance teaching practice. For example, case discussion has been identified as powerful tool to explore teaching practice (Hutchings, 1993). Other researcher [Culver, 1990 & Edgerton, et al., 1995] suggested teaching portfolios during peer monitoring as effective tool in achieving the constructive reflections. One of the main objectives of the reflection practice on the early design project is to achieve the deep approach in the learning process. Moon (1999) has demonstrated the importance of reflections procedures in learning which appears significantly in attaining deep understanding. He suggested that there is a fundamental difference in success in learning between adopting a 'deep' approach and a 'surface' approach to a learning task. A deep approach is where the intention of the learner is to understand the meaning of the material. In contrast, a surface approach to learning is where a learner is concerned to memorize the material for what it is, not trying to understand it in relation to previous ideas or other areas of understanding. The surface approaches to learning include noticing and making sense, while the deep approaches consist of making meaning, working with the meaning and transformative learning, in addition to the two points mentioned in the case of surface approaches.

The proposed early design project is belonging to the Mechanical Engineering Science 2, which is offered in first year, second semester. This course is designed to achieve an appreciation of why certain materials acquire certain crystal structure and how it influences their mechanical properties coupled with an appreciation of the response of engineering materials to mechanical and thermal loading and to know when and how to apply the taught concepts to real world problems in these fields of engineering science. The main purpose of this study is to examine the effects of this early design project in achieving several learning objectives throughout quantitative reflections of the students and qualitative reflections of the instructors. In the next section, the description of the project, approach, structures and processes are identified.

2. Description of the Project

The structure of the integrated design project team consists of four team members at first year level and a fourth year student as a group leader, in addition to the course instructor and an external professor from different departments working as a team consultant. Some statistical data about participants who joined this project are shown in Table 1. The objectives of the project are defined by the course instructors and the group members are responsible for achieving the objectives using the available resources set by the school. The project teams were formed during the first week of the semester. Group leaders were given the opportunity to participate in the process of forming the teams. Team members met regularly every week and the engineering labs were open for them to carry out the work associated with the design project such as measurements and experiments. In the next paragraphs, the project statement and tasks are briefly presented.

Table 1 Statistics about the involvement of students and instructors in the early design project

No. of Students enrolling the module	Mechanical Engineering	60
	Civil Engineering	33
	Automotive Engineering	5
	Engineering and Management	6
No. of Supervisors participated in the project evaluation	Mechanical Engineering	4
	Civil Engineering	2
	Electrical Engineering	4
	Engineering and Management	1
No. of 4th year students participating in the groups	Mechanical Engineering	20
	Civil Engineering	0
	Electrical Engineering	5
	Engineering and Management	0
Total No. of Students		104
Total No. of Groups		25

2.1 Project Statement: Aims and Objectives

The project objective, as outlined to the students, was to design, build and test a prototype device which can generate electricity from free energy sources. The project is required to be innovative and applicable as daily use device which may contribute to energy savings in electrical appliances. The students were advised to carry out this project with a maximum budget of 50 USD for each group. This amount was allocated and funded by the Engineering and Physical Sciences School. We did not explicitly advise students what knowledge, skill or technique to use in order to promote students creativity. The expected learning outcomes of this project can be classified into two main categories: technical and educational aspects. From the technical objectives point of view, the students are required to learn and perform the following tasks:

- Clearly define the main components of the proposed device using illustrative CAD drawings.
- Assembly of the device by describing the experimental setup and assembly processes.
- To show a successful experimental run for the proposed design under operating conditions.
- To verify the obtained results mathematically by providing a simple mathematical model of the proposed device.

One of the main educational goals was to encourage the 1st year students to use their natural design in a free form and brainstorming manner, with the minimum formal guidance from their supervisors. Also this project was designed to encourage students to work in teams despite the variety of their majors, and lead them implicitly toward the deep approach in learning.

2.2 Assessment Criteria

In this early design project, the students were asked to submit one progress report, final report and presenting their work at the end of the module. The project assessment was weighted as follows: progress report (20 %), final report (50 %) and presentation (30 %). The final report was assessed by the module leader only and it was weighted according to the following components: Literature review (10 %), technical content (15 %), format of the report (10 %) and critical evaluation (15 %). Table 2 shows the assessment criteria for each component. The presentation of each group was assessed by all supervisors who participated in the project. The presentation of the final project and the ability to convey the essence of the proposed approach required strong oral; and written communication skills. The assessment form for the presentation is shown in Appendix A.

Table 2 Assessment Criteria for the final report

CATEGORY (WEIGHTING/ 50)	A EXCELLENT	B VERY GOOD	C GOOD	D PASS	E CREDIT PASS	F FAIL
LITERATURE REVIEW (10)	Has identified the relevant literature and previous work and theory relevant to the project. Appropriate referencing critically reviewed.	Has identified most of the relevant literature and previous work and theory relevant to the project. Appropriate referencing, most critically reviewed.	Has identified an acceptable proportion of the relevant literature and previous work and theory. Some referencing discussed.	Has identified some relevant literature and previous work and theory. Some referencing discussed.	Has identified a limited number of examples of relevant literature and previous work and theory.	Has NOT identified sufficient examples of relevant literature or previous work or theory.
FORMAT/ PRESENTATION (10)	Excellent use of formatting, graphs, images, equations, etc. clearly presenting all ideas/results/principles. Excellent grammar and spelling with appropriate academic written style.	Very good use of formatting, graphs, images, equations, etc. clearly presenting most ideas/results/principles. Very good grammar and spelling with appropriate academic written style.	Good use of formatting, graphs, images, equations, etc. clearly presenting some ideas/results/principles. Good grammar and spelling.	Some use of formatting, graphs, images, equations, etc. presenting some ideas/results/principles. Poor grammar and some spelling mistakes.	Poor use of formatting, graphs, images, equations, etc. Difficult to understand some ideas/results/principles. Parts missing or wrongly presented. Poor language and grammar and some spelling mistakes.	Very poor presentation using inappropriate methods which fail to present the ideas/results/principles involved. Language, grammar and spelling poor.
TECHNICAL CONTENT (15)	Has correctly applied the ideas/principles and interpreted results.	Has correctly applied most of the ideas/principles and interpreted results.	Has correctly applied an acceptable proportion of ideas/principles and interpreted results.	Has correctly applied some of the ideas/principles and interpreted some results.	Has applied some of the ideas/principles in some cases.	Has shown little/no evidence of application of ideas/principles and/or interpretation of results.
CRITICAL EVALUATION (15)	Excellent extensive critical evaluation and analysis and discussion within project. Rigorous and appropriate analysis.	Excellent critical evaluation and analysis and discussion within project. Generally rigorous and appropriate analysis.	Some critical evaluation and analysis and discussion. Rigor in analysis could be greatly improved.	Little critical evaluation or analysis or discussion. Analysis not rigorous.	Misguided critical evaluation/analysis within assignment. Poor discussion. No rigor.	Lacking critique and rigor.

3. Overview of Early Design Project Results

In order to encourage brainstorming and creativity of students, they got full freedom to select their projects provided that they should meet the project statement (i.e. Section 2.1) and not to exceed the offered budget. It was noticed that students provided wide variety of electricity generation devices powered by wind energy, solar energy, wave energy, heat sources and free hydraulic energy resulted from falling waters in drainage pipes. The generated electricity was satisfactory for home lightening purposes and operating low voltage home appliances. Students provided detailed design and assembly drawings, and were able to show live experimental runs during their presentations. Figures (1-4) show a sample of the submitted projects.

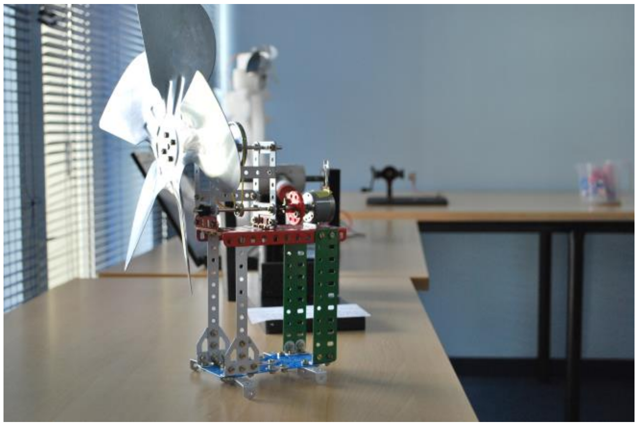

Fig 1. Mini wind powered generator

Fig 2. Hub Dynamo model

Fig 3. Mini wave energy generator

Fig 4. Miniature electrical generator

4. Results, Reflections and Discussion

In this early design project, students were asked to hold weekly meetings for the group and regular meeting with their supervisor, while the minutes of meeting were required to be submitted along with their final report. In order to follow up the students in regular basis, students were required to submit a progress report at the mid of the semester, showing their basic design and elementary work. At the end of the semester, all teams conducted oral presentations and submitted a final report for the design project. The presentations of the projects were open to all from university and industry as the students were required to communicate their results publically. The overall mark of this project consists of 20 % of the total module grade. Based on the assessment criteria presented in section 2.2, the students' results out of 20 are illustrated in Fig. 5. In order to verify the effect of the early design project on the performance of students, the students' scores in this project were compared to their course work in another module during the 1st semester (i.e. Mechanical Engineering Science 1) where project based learning was not involved. The obtained results presented in Fig. 6 showed a noticeable increase and improvement in the student's score of the present course with integrated PBL component compared to a similar course without PBL. This trend may reflect that students' performance was improved and this assures the pedagogical statement that students learn best when they enjoy to learn rather than pushing them toward routine assignments. This agrees with Benjamin Franklin quote: *"Tell me and I forget, Teach me and I remember, Involve me and I learn"*.

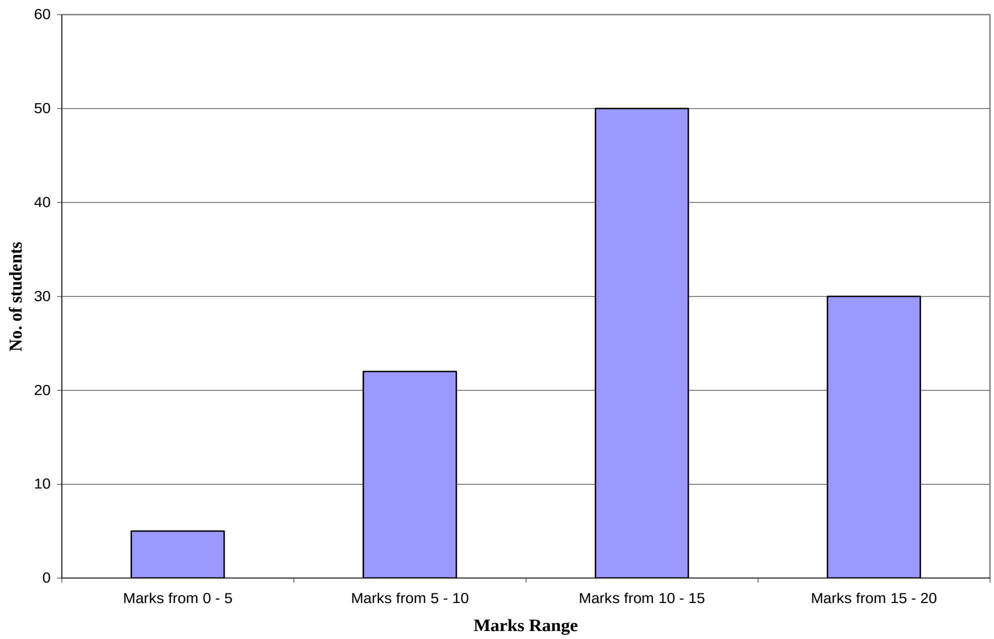

Fig 5. Assessment results of the first year design project (Out of 20)

Surveys were carried out at the end of second semester to investigate how first year students rated the overall experience. The survey contained 12 questions as shown in table 3. The form of survey distributed to the students at the end of the semester is shown in Appendix B. The survey questions have been chosen to measure four main objectives: personal gain of knowledge, social benefits resulted from collaborative work, learning from experience and developing self-learning skills. The students' responses of this survey were presented by the histogram shown in Fig. 7. The results from the survey showed that students have enjoyed working in the project because of the relations established with peers as well as fourth year students. These interpersonal relations have increased their learning abilities and confidence. Students recognize the benefits of team work and cooperative learning. The project also helped first year students to discover the importance of mathematics and science in engineering design. One of the important features of this project was teaching students how to learn by themselves with minimum guidance from their supervisors. Also it was found that this project assists students in developing their skills gradually during the semester and to come up with creative designs and successful relevant analyses.

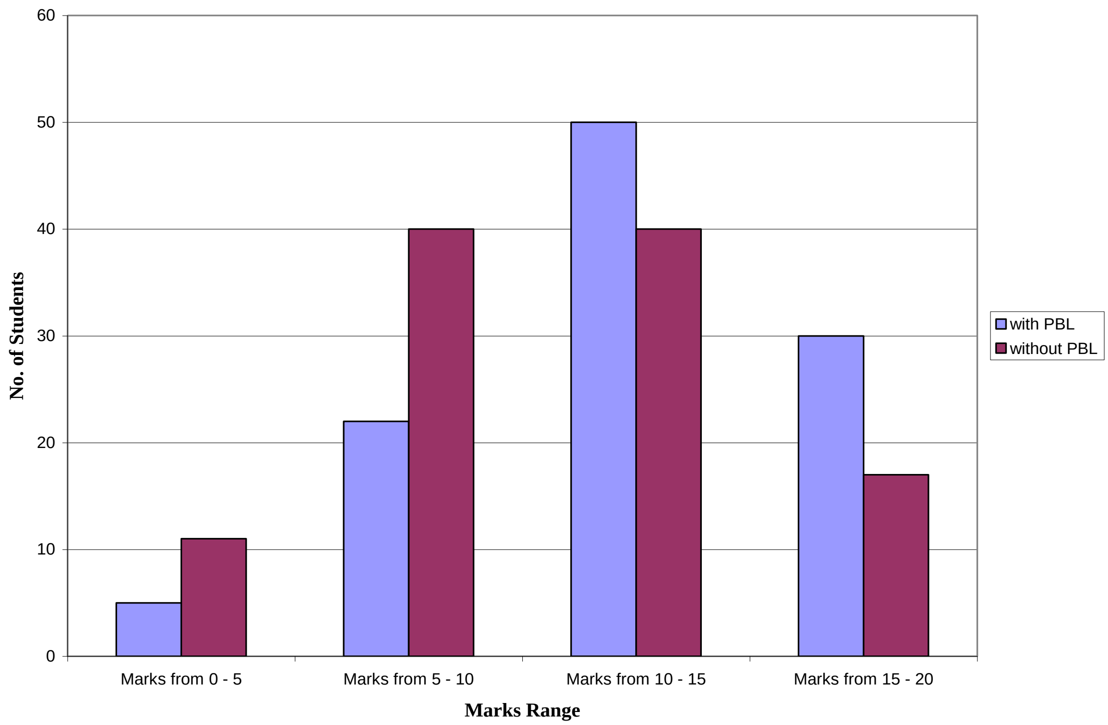

Fig 6. Marks obtained by students in two different courses with and without PBL (Out of 20)

Table 4 Survey Questions

Question No.	Question	Question No.	Question
Q1	My design skills were improved	Q7	I was able to link ethical responsibility to the project
Q2	My theoretical and analysis skills were put into practice	Q8	I have gained better understanding of the science, math and engineering principles
Q3	I was able to bring knowledge of social and political issues to the design project	Q9	I have benefited from the help of senior students at the school
Q4	My presentation skills were improved	Q10	I have enjoyed the time spent in the working of the project
Q5	I have contributed effectively to the economic analysis and business planning of the project	Q11	I have gained awareness of the environmental impact of energy uses
Q6	I was able to contribute effectively in a multi-discipline team	Q12	I have learnt to work with others

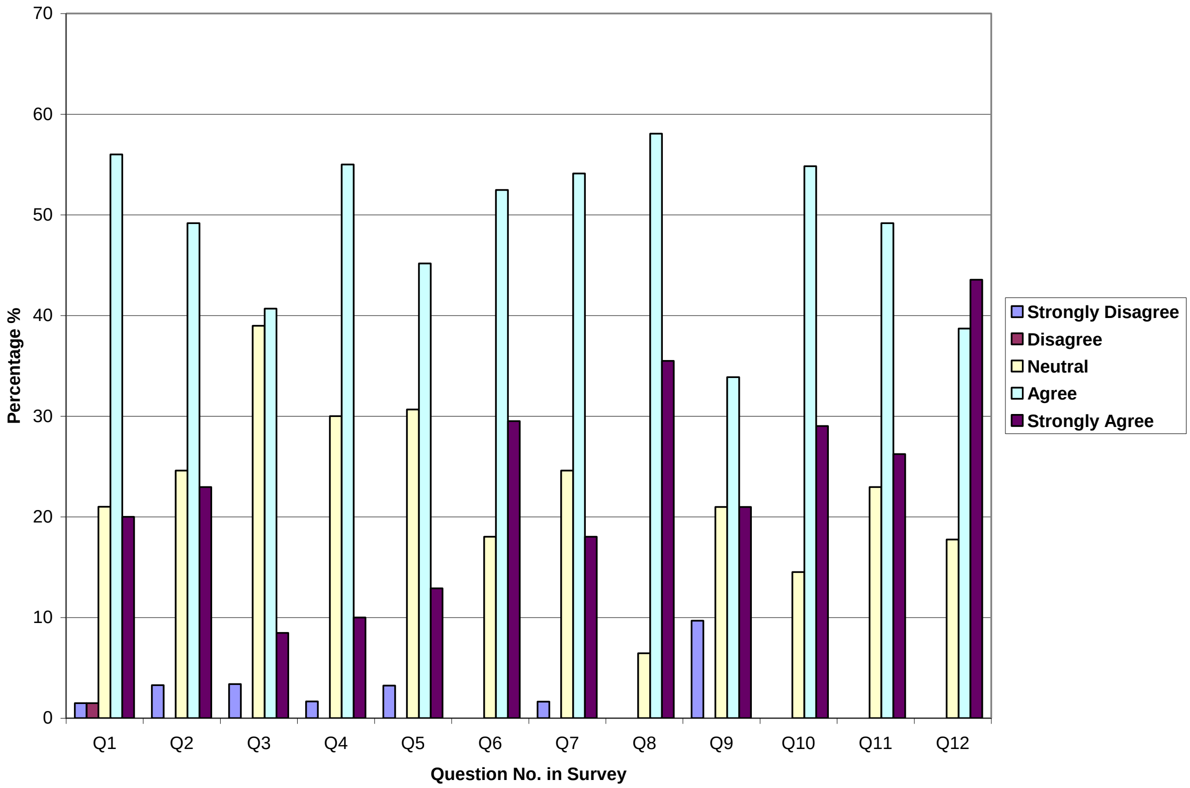

Fig. 7. Response and results of the students' survey

In order to investigate the reflections among the professors who were participated in this early design project, qualitative analysis of the professors opinions related to the project technique was carried out. The professors who have taught the course demonstrated that the performance of students was noticeably upgraded during the semester. The module leader stated that "*This early design project was an efficient tool for motivating the students of the importance of mechanical engineering science module for engineers; this was verified by a noticeable increase in the attendance and submission of the assignments during the semester*". Most of the project supervisors indicated that this early design project was successful to introduce the early stage students to the real life applications. One of the supervisors said *"This multidisciplinary project proved for students the strong interaction between engineering disciplines exists in the real life, and collaborative team work is necessary to achieve creative designs"*. Many of the professors who attended the presentations but didn't participate in the project highlighted the importance of this project in feeding the students with the basic presenting skills. One of them commented saying "*At this early stage, it is useful to expose students to presenting their work and discuss it in public, as it is a dominant factor in achieving high confidence by themselves and their knowledge*". On the other hand, most of them showed high interest to participate in this project in the next year.

5. Conclusions

This research focused on the implementation of the integrated early design project for the 1st year multi discipline engineering students. The project involves integrating horizontally four first year students from different departments and vertically a fourth year student as a group leader. The technical objective of this project was to develop an efficient device which can generate electricity from green energy source with a fixed budget of up to 50 USD. There is no further problem statement and the slight ambiguity in the given information was intentional to encourage the students' innovation and to reflect accurately their own creativity. The solution is definitely can be obtained with more than one valid approach. The main learning objective of this study was to investigate the effects of this kind of multidisciplinary early design project in enhancing the students' knowledge and improving their technical and communications skills. Based on the submitted projects, it was noticed that students were able to develop a wide variety of electricity generation devices powered by wind energy, solar energy, wave energy, heat sources and free hydraulic energy resulted from falling waters in drainage pipes. Quantitative and qualitative surveys showed that the introduction of this early design project was successful and positive feedback received and the constructive objective indicators reflected the satisfaction of all people involved (students, professors, and other staff). Overall, the outcomes of this education experience was impressive, this can be attributed to the enthusiasm of the students involved (first year and fourth year) and by the novelty of the topic, and in the management and facilitation of the project. These results confirmed our early opinion of the success of the integration of students in the teaching and learning process. It gave the students an opportunity to become an active part of the educational process. This activity may help them in developing their learning process as well as in their professional careers. The experiment of the integrated design project can be applied and exported to other engineering courses.

Acknowledgement

The authors greatly appreciate the support provided by Heriot-Watt University during this research.

References

Agogino, A.M., Sheppard, S.D., and Oladipupo, A., 1992. Making Connections to Engineering During the First Two Years, Proceedings, 1992 Frontiers in Education Conference, Institute of Electrical and Electronic Engineers.

Barron, B., 1998. Doing with understanding: Lessons from research on problem- and project-based learning. Journal of the Learning Sciences, 7(3, 4), 271–311.

Clive, L., Dym, Alice M., Agogino, A. M., Ozgur Eris, Daniel D., Frey and Larry J. Leifer, 2005. Engineering Design Thinking, Teaching, and Learning, Journal of Engineering Education, Vol. 94, No. 1, 2005.

Culver, R. S., 1990. Motivating faculty to improve teaching: Four practical suggestions. In Proceedings of ASEE Annual Conference. Toronto, Canada.
PMCid:PMC53286

Dewey, J., 1933. How We Think: A restatement of the relation of reflective thinking to the educative process. Boston: D.C. Heath.

Dym, C.L., 1994. Teaching Design to Freshmen: Style and Content, Journal of Engineering Education, 83, No. 4, 303–310.
http://dx.doi.org/10.1002/j.2168-9830.1994.tb00123.x

Dym, C.L., and Little, L., 2003. Engineering Design: A Project-Based Introduction, 2nd ed., New York, N.Y.: John Wiley, Edgerton, R.; Hutchings, P.; & Quinlan, K., 1995. The Teaching Portfolio. The American Association of Higher Education: Washington, D.C.

Giralt, F., Herrero, J., Grau, F.X., Alabart, J.R., and Medir, M., 2000. Horizontal and Vertical Integration of Education into a Human-Centered Engineering Practice in Design Processes, Journal of Engineering Education, 219- 229.

Hutchings, P., 1993. Using Cases to Improve College Teaching. The American Association of Higher Education: Washington, D.C.

Ivan Milentijevic, Vladimir Ciric and Oliver Vojinovic, 2008. Version Control in Project-Based Learning, Computers and Education 50, 1331-1338.
http://dx.doi.org/10.1016/j.compedu.2006.12.010

Moon, J., 1999. Reflection in Learning and professional Development, Kogan Page, London.

Pavelich, M. J., Olds, B.M., and Miller, R.L., 1995. Real-World Problem Solving in Freshman/Sophomore Engineering, in Gainen, J. and Willemsen, E., eds., Fostering Student Success in Quantitative Gateway Courses, San Francisco, Cal.: Jossey-Bass,

Rhodes, C. and Garrick, J., 2003. Project-Based Learning and the Limits of corporate Knowledge", Journal of Management Education, 27(4), 447-471.
http://dx.doi.org/10.1177/1052562903255859

Sheppard, S.D., 2003. A Description of Engineering: An Essential Backdrop for Interpreting Engineering Education, Proceedings (CD), Mudd Design Workshop IV, Claremont, Cal.: Harvey Mudd College.

Simon, H.A., 1999. The Sciences of the Artificial, 3rd ed., Cambridge, MIT Press.

Thompson, K.J. and Beak, J., 2007. The Leadership Book: Enhancing the Theory-Practice Connection Through Project-Based Learning", Journal of Management Education, 31(2), 278-291.
http://dx.doi.org/10.1177/1052562096297143

APPENDIX A: Assessment form of Early Design Project Presentation

Comments	Mark
1. Introduction and Understanding of the Project Does the presentation contain: ▪ An understanding of the brief of the energy conversion system. ▪ The group's interpretation how is the volume of usage similar energy source in generating electricity across wide-used industrial applications. ▪ A well-defined objectives and Statement of Requirements.	**Marks out of 5** ( )
2. Theoretical Background Does the presentation contain in brief the basic scientific principles and theory behind the selected energy conversion model?	**Marks out of 2** ( )
3. Experimental Setup ▪ Description of the experimental setup. ▪ Description of the assembly process. ▪ Clearly defined the system components using illustrative drawings.	**Marks out of 8** ( )
4. Experimental run Does the presentation contain a successful Experimental run which shows both ability and efficiency of selected system in generating electricity? **Note:** This can be achieved by either performing the experimental run during the presentation or providing a demo video.	**Marks out of 7** ( )
5. Results, Discussion and Conclusions ▪ Does the presentation contain the main experimental results and brief discussion of them?	**Marks out of 3** ( )
6. Presentation Structure Is/does the presentation: ▪ Well presented, with correct language and grammar ▪ Well structured (logical presentation in sections)	**Marks out of 5** ( )
Total Mark	**Marks out of 30** **(%)**

Assessor:	**Signature:**

APPENDIX B: Survey Form distributed to students

Survey Questions

1. Year /Level: 1 ☐ 2 ☐ 3 ☐ 4 ☐
2. Gender: Male ☐ Female ☐
3. High School system attended: ☐

		Strongly Disagree 1	**Disagree 2**	**Neutral 3**	**Agree 4**	**Strongly Agree 5**
1	My design skills were improved.					
2	My theoretical and analysis skills were put into practice.					
3	I was able to bring knowledge of social and political issues to the design project.					
4	My presentation skills were improved.					
5	I have contributed effectively to the economic analysis and business planning of the project.					
6	I was able to contribute effectively in a multi-discipline team.					
7	I was able to link ethical responsibility to the project.					
8	I have gained better understanding of the science, math and engineering principles.					
9	I have benefited from the help of senior students at the school.					
10	I have enjoyed the time spent in the working of the project.					
11	I have gained awareness of the environmental impact of energy uses.					
12	I have learnt to work with others.					