Ethics in Engineering Education: A Literature Review

Jehan Abu Hamad, Maram Hasanain, Mahmoud Abdulwahed, Rashid Al-Ammari*
College of Engineering, Qatar University, Doha, Qatar

** Corresponding Author: m.abdulwahed@qu.edu.qa*

***Abstract*— Engineering Ethics is an important topic to be developed in engineering education curriculum. Despite its importance, ethics is not much investigated in engineering education as compared to other disciplines, in particular medicine or biology education. In this paper, a comprehensive review of engineering ethics is provided. The review covers three main topics: 1) Attributes of ethical engineers, 2) Content, logistics and pedagogy of engineering ethics, and 3) Assessment of engineering ethics. A particular focus is given to the Defining Issues Test (DIT) and the Engineering and Science Issues Test (ESIT) that is considered a promising instrument to assess moral judgment development of science and engineering students. Final remarks will conclude the paper.**

Keywords*— *Engineering Ethics, Ethics Assessment, Ethics Pedagogy

I. Introduction And Definitions

Recent advances in engineering complexity requires engineering graduates who are able to handle interrelated technical, social, human, and complex issues [1]–[2]. The engineering profession mission requires the engineer to contribute to human welfare by reshaping the social, economic and legal contexts [3]–[4]. Hence, engineering profession is not only about the application of technical knowledge, but it is also about the application of technical knowledge in an ethical manner. Engineering ethics is taught to engineering students as a practical academic discipline that deals with real life situations, whereas an engineer's responsibilities are more complex than ever. Therefore, the professional responsibilities are introduced through these ethics to prepare the students for real life ethical dilemmas [5]. Ermer and VanderLeest [6] define engineering ethics in accordance to Martin and Schinzinger [7] as "the study of the moral problems confronted by individuals and organizations involved in engineering". Another definition of engineering ethics was proposed by Li and Fu [8] as a field which "*consists of the responsibilities and rights of those engaged in engineering, and also their desirable ideals and personal commitments*". They add, ethics "*is the study of the decisions, policies, and values that are morally desirable in engineering practice and research*".

Engineering ethics education plays a significant role in the formation and reshaping of the engineer's ethics. Possible objectives for ethical instruction in engineering education have been reported in the literature. Newberry [1] in accordance to [9] highlighted some of these objectives as follows: "i) stimulate the ethical imagination of students, ii) help students recognize ethical issues, iii) help students analyze key ethical concepts and principles, iv) help students deal with ambiguity, v) encourage students to take ethics seriously, vi) increase student sensitivity to ethical issues, vii) increase student knowledge of relevant standards, viii) improve ethical judgment, and ix) increase ethical will-power".

II. Attributes of an Ethical Engineer

The engineering profession positions the engineer in numerous ambiguous or conflicting situations of various types; a common example is facing ethical dilemmas. In order to tackle ethical dilemmas, the engineer should possess the necessary ethical skills and attributes. Li and Fu [8] highlighted a set of skills an ethical engineer should hold present in [10]. An ethical engineer should have the skill to: define ethics issues, identify relevant socio technical systems, understand different perspectives, identify and recognize value conflicts, identify constraints, identify and assess decisions (in terms of: barriers, consequences and defensibility), engage in ethical reasoned negotiations and finally, revise plans/actions/options.

Reasoning and critical judgment skills are essential for engineers while handling ethical situations. Steneck [11] highlighted that engineers should posses ethical reasoning skills, and should be able to understand the interrelation between technology and society.

Another ethical engineer's profile and set of ethical attributes were suggested by Devon [12]; these are: competency, cognizance, democratic information flows, democratic product design and development teams, a service orientation, diversity, cooperativeness, creativity and project management skills. These attributes act as guidelines for the engagement process of the engineer with other individuals. The understanding and application of such eliminates the reliance on individual ethics. Competency includes the engineer's realization of a product that achieves the goals of money making, protection of infrastructure and the protection of the country. An important attribute is cognizance, i.e. an engineer should have a full understanding of the implications of the decisions and designs they propose. Open democratic information flows includes the respect flowing between the participants while sharing information.

978-1-4673-5261-1/13/$31.00 ©2013 IEEE

Development teams and product design processes must be aimed towards achieving technology of the people, for the people and by the people. An ethical engineer should value diversity and avoid stereotyping. Cooperativeness is essential and without such cooperation the productivity of an unsafe product or decisions becomes a potential risk. New creative innovative ideas are demanded by an ethical engineer. Finally, an ethical engineer should possess project management skills. Knowing what expertise and duties are required, and knowing how to assign and manage them is necessary.

A significant portion of the skills and attributes of an ethical engineer are related to morality. Several moral models have been conducted. The paper proposed by Illingworth [13] in reference to [14] summarized the Four Component Model (FCM) of Morality:

1) Moral sensitivity (interpreting the situation as moral).
2) Moral judgment (judging which of the available actions are most justified).
3) Moral motivation (prioritizing the moral over other significant concerns).
4) Moral character (being able to construct and implement actions that service the moral choice)

Based on the literature review conducted in this area [8], [10]-[14]; an optimum model of the ethical engineer was created.

An ethical engineer should have the skills to identify an ethical dilemma and all the constraints related to such dilemma. He/she should communicate effectively with other team members to assess barriers and any possible consequences. Negotiation skills are required when team members decide upon a final ethical decision. Skills of reasoning and understanding of the relationship between both engineering and the society, and technology and society are also essential. Understanding also includes the understanding of different diverse perspectives. An ethical engineer should be competent and service oriented. The identification and recognition of value conflicts is necessary. The exchange of information between colleagues in a democratic form is also a required skill. Part of being an ethical engineer is related to moral sensitivity, judgment, motivation and character. Being creative and having strong project management skills is a must for an ethical engineer. Finally, an ethical engineer should have the skill to revise plans/actions/options.

III. Mechanisms of the Provision of Engineering Ethics Education

Several concerns were raised regarding the engineering ethics education; does it really influence the ethical skills as planned, what is the most suitable and effective approach to teach ethics. Numerous research studies were conducted in this field [3], [5], [8]–[9], [11], [13], [18]–[19]. Stand-alone ethics courses are the most common mechanism, but the introduction of engineering ethics in technical courses is highly recommended [9]. Throughout this review, the delivery methods noticed revolved around three main methods: 1- standalone courses, 2- embedded courses, and 3- team taught courses.

A. Standalone Courses Approach

As suggested by Li and Fu[8]; a standalone course is an independent course usually taught by one professor, not necessarily a professional in ethics. It is also easy to select what topics should be covered. Engineering ethics can be conducted through: standalone ethics courses within engineering or standalone ethics courses from outside engineering [1], [5], [18]. Stephan [5] suggested some "Credit-Hour-Friendly ways of teaching ethics" that were such as "Politics and Ethics of Engineering". A disadvantage of such approach is that it overcrowds the engineering curriculum which is already crowded [20].

B. Embedded Courses Approach

An embedded approach includes the introduction of ethics in different engineering core courses. This is accomplished by incorporating an ethical component or module into actual engineering courses [8]. It includes the integration of ethics content in all technical courses [1], [5], [18]. A series of contextualized activates are used to perform the integration of ethics into the engineering curriculum. This integration is considered an advantage for such approach [20]. An example of an integrative course that includes both technical and non-technical ethics mentioned in [5] was adopted in Drexel School. To further emphasize on the "across curriculum/embedded" approach, the College of Engineering at the University of Michigan adopted this approach for teaching engineering ethics along with the issues of communication, teamwork and environment [11]. The high dependency of the course on the willingness of the faculty member to address ethics decisions in his/her course is considered are the main disadvantage of such approach [8].

C. Team Teaching Approach

Team teaching approach delivers a course which is taught by a team of multidisciplinary professors [21]–[22]. Such approach gives the students that advantage of learning form the diverse expertise of both the engineering professors and the philosophy professors. The main difficulty of such approach is related to finding highly motivated and qualified engineering professors to deliver such course [8].

Some examples of the approaches used to teach engineering ethics in the undergraduate level are: "Segments in Introduction to engineering courses, Segments in Senior Seminars, Segments in Capstone Design Courses, Pervasive Approach, Integrated Humanities Courses, and Stand-alone Courses" [15]. A new approach for teaching engineering ethics is expected to include guidance by experts in making ethical decisions, harmonizing the ethics with the engineering curriculum and finally strongly demonstrating that ethics is an integral component in all engineering practices [19].

IV. Pedagogy

Several researches have been made to define the paramount methods to deliver the curriculum of engineering ethics. The review conducted resulted in numerous delivery approaches such as case studies, ccollaborative/challenge games and role plays, debates and group discussions, presentations, codes of ethics, online instruction, multimedia packages, videos and simulation, and traditional teaching methods [3], [8]–[9], [16], [23]–[30].

A. Case Studies

The best method to teach engineering ethics as mentioned in [9] is by using several case studies, e.g. disasters cases. The cases used are cases which are more likely to be encountered in real life situations. Using case studies provides a framework which engages the students in problem solving themes; they also can become a platform for peer to peer learning and experiences exchange. During such cases, the students train their moral imagination as a result of the

holistic effect the case approach has [16]. Case studies force students to draw the line between acceptable and unacceptable actions and behaviors [9]. Involving students in case studies strengthens their ethical reasoning skills [23]. Such method provides the exchange of experiences between students and faculty [16]. Some examples of utilized case studies are: Challenger launch decision, BART case [8]; The Hyatt Kansas walkway collapse, West Gate Bridge, and the Thredbo disaster [23].

B. Collaborative/Challenge Games and Role Plays in Ethics Education

Practical understanding of ethical issues, specially the concept of responsibility, can be attained by designing collaborative games [26]. Skills of negotiation, strategic planning, public speaking, and evidence presenting are some of the skills games provide the students with. The "Engineering Ethics Challenge Game" as mentioned by Carpenter [27] involves a large number of ethical cases. Students get involved in without losing interest or feeling bored. Teamwork skills, ethical reasoning and problem solving skills are developed during such game. Such games provide an excellent chance for group discussions and emphasize on teamwork and collaboration between students [8]. Lloyd and de Poel [26] highlighted that games with their competitive environments provide students an informative experience in the management of open ended situations.

C. Debates and Group Discussions

An approach to improve the engineering ethics education is to involve the engineers in debates that aim to develop the uses of technology [3]. Such debates improve the ethical reasoning skills of students and the exchange of information and opinions. Debates focus on the idea of respecting other opposing opinions. While debating, students have the chance to fully analyze an ethical situation from all its aspects, i.e. design, technical and statistical considerations [24].

D. Utilization of Online Instruction

Loui [28] suggested that online educational technologies used in teaching engineering ethics have many benefits over traditional educational technologies. It opens the space for communication between students with each other and between the students and instructors [30]. Archiving of class sessions is one main advantage of such method. Access via the Internet to course resources is possible by this type of instruction [28].

E. Utilization of Codes of Ethics

Schmaltz [24] highlighted that the introduction to existing codes of ethics will increase the students level of knowledge and comprehension. Implicit social contract between society and professionals is also achieved. Being aware of the codes of ethics helps the students understand the professional societies role [23]. Stern and Russell [29] suggested a module to teach engineering ethics more effectively. In this module, students work on developing their own code-of ethics; Once developed, they compare them to established codes by engineering societies.

F. Other Methods and Approaches

Multimedia packages, videos and simulation provide an interactive learning framework for students [8]. The use of presentations as a method to teach engineering ethics is recommended by Bowden [23]. During presentations, students with their peers have the chance to discuss their viewpoints and draw conclusions. Group work and cooperation among students is achieved when preparing and giving presentations [28]–[29]. Traditional Methods including exams, reports, quizzes, assignments, etc. are still used in which analytical skills are used and measured [24]. The previous methods are summarized in the table below.

TABLE I. ENGINEERING ETHICS INSTRUCTIONAL METHODS AND OUTCOMES

Instructional Method	Expected Outcome
Case Studies	• Strengthen the ethical reasoning [23] • Engagement in life time ethical concerns [23] • Encountering of real life situations [9]. • Drawing the line between acceptable and unacceptable actions and behaviors [9]. • Engage students in problem solving themes [16]. • Exchange of experiences [16]. • Awareness of harmful practices [24] • Demonstration of ethical issues [25].
Collaborative/Challenge Games and Role Plays	• Practical understanding of ethical issues (responsibility) [26] • Teamwork [27]. • Ethical reasoning [27]. • Negotiation, strategic planning, public speaking, and evidence presenting [26]. • Group discussion [8]..
Debates and Group Discussions	• Exchange opinions and respect others opinion [3]. • Improve the ethical reasoning skills • Analyze ethical situations from all its aspects [24].
Presentations	• Discuss viewpoints and draw conclusions [23]. • Cooperation among students [28].. • Groupwork [29]..
Traditional Methods (Exams, reports, quizzes, assignments, etc)	• Application of analytical skills [24]. • Groupwork [29]..
Codes of Ethics	• Increase the level of knowledge and comprehension [24].. • Understand the professional societies role [23] • Understanding of class-wide codes of engineering ethics [29].
Online instruction	• Communication [28] ,[30]. • Production of documents, drawings, and other artifacts [28] • Train the students moral imagination [16]. • Prompt Feedback [28] • Archiving of class sessions [28]. • Management of open ended situations [26] • Access via the Internet to special resources [28]..
Multimedia packages, videos and simulation	• Interactive framework [8].

In this section, an overview of the most common methods of engineering ethics instruction has been provided. The next section provides more details on the contents deployed in these methods. Examples of where these methods are applied are also mentioned.

V. CONTENT

The content of the curriculum must provide the knowledge and skills the future engineer needs to face the ethical challenges of today's world [8]. It should increase student's knowledge of relevant ethical standards. The

curriculum must be designed improve the ethical judgment and ethical willpower of students [9]. The main ethical issues taught in US engineering schools are enumerated in [23]: Public safety and welfare, risk and informed consent, health and environment, representation of data, whistle-blowing issues, conflict of interest, accountability to clients, plagiarism or giving due credit, quality control, confidentiality, gift giving and bribes, employee relations and discrimination. Many methods of teaching engineering ethics were reviewed in the previous chapter. This section focuses on the content of two main engineering ethics educational pedagogies, online instructions and games/role plays.

A. Online Instruction

Instruction using the internet (web-based instruction) bridges cultural gaps and distances between both students and instructors [31]. Several reviews have been made and the following are three examples of applied web-based instruction [11], [30], [32]. Simulator for Engineering Ethics Education (SEEE):

As reviewed from Chung and Alfred [30], the SEEE is an online interactive simulator for engineering ethics education. The students are placed in scenarios which involve several ethical dilemmas, where they have to solve in a first perspective manner. During the first perspective scenarios, the students are obliged to perform an action rather than only observing the situation. The action includes playing the role of an agent and making serious decisions regarding the collection of more evidence, raising of ethical issues, and finally how to best support their ethical concerns**.**

The SEEE has four modes of operation:

a) Instructional mode: "fundamental information about engineering ethics, rules of practice, and professional obligations."

b) Training mode: "specific scenario segments involving the recognition and response to the engineering ethics subjects presented in the instructional mode."

c) Scenario mode: "complete first person perspective scenarios involving different types of possible engineering ethics situations."

d) Evaluation mode: "provide users with an objective means of assessing the level of the user's knowledge."

Comparison was made between the SEEE method and the "conventional web based engineering ethics education resource". A 32% improvement in instructional effectiveness was noticed compared to the conventional web resources [30]

1) Responsible Engineering Forum (REF@UM):

The forum was developed by the University of Michigan, it aimed to engage engineering faculty members in the teaching of engineering ethics in engineering classes. The structure of the REF@UM website is as follows:

a) Main content: divided into four sections (4 levels of ethics introductory courses)

b) Course sections: resources specifically designed to support teaching at each of the four levels (readings, links to other sites, interactive materials, and assignments)

c) Separate, password-protected section: materials specifically for faculty

d) Additional links: to locate other ethics sites, career information, professional societies, codes, journals, and case studies [11].

2) Websites for ethical engagement

A website developed by Imperial College London for the purpose of ethics engagement.

The website was developed in the form of an online ethics advisor. The three main aspects are:

a) A search tool: from which the user can get statistics and specific references to codes of conducts to ethical questions or problems.

b) A polling element: so that users can give their view on ethical matters.

c) A forum: for people to discuss any ethical issues they may have.

B. Games/Role Plays

Skills of negotiation, strategic planning, public speaking, and evidence presenting are some of the skills games provide the students with. These games with their competitive environments provide students an informative experience in the management of open ended situations [26]. The Engineering Ethics Challenge and the Delta Design Game are examples of these games.

1) Engineering Ethics Challenge (EEC):

University of South Florida developed the EEC to encourage teamwork, experience exchange and responses to ethical dilemmas. The EEC game includes questions based on ethical situations. A typical class is divided into 6 groups. Each group has a name. Ethical situations are assigned for each group. Each group develops EEC questions based on these situations. They also develop multiple choice responses. The responses are formulated in a PowerPoint presentation. To begin, a group presents their questions and several responses to all the class. The rest of the groups are asked to discuss the question and choose one of the responses. An expert, usually the class moderator, is given the scoring of the responses made by the remaining groups. The performance of the presenting group is criticized based on their presentation skills, communication skills, their understanding of the codes of ethics and the clarity of their responses. Based on this critique, the playing group makes their move on the EEC board and another group makes their presentation. The group which moves the furthest is the winning group [27].

2) Delta Design Game (DDG):

The Delft University of Technology developed such game to train students for a full design process including all types of ethical dilemmas. In this game a group of multidisciplinary designers work together to design and construct a building which is suitable and at the same time attractive for inhabitants of DeltaP company. This game is used mostly in business sectors. The same idea can be applied with the undergraduate students in which seven groups each consisting of 4 to 6 students. The game is played for almost 3 hours where students propose solutions and start discussing their proposals. Judgments are made concerning the trust of the "rule of thumb" guidelines given. Several conflicts will arise during the game and the students will try to come up with the optimum solution to solve these conflicts [26].

Developing an engineering ethics education approach and applying it is not enough. An assessment of the developed approaches must be constructed to assess the effectiveness of the engineering ethics educational treatment. The following section covers the assessment instruments used to evaluate the effectiveness of ethics educational approaches.

VI. ASSESSMENT

Several research studies have tried to examine the effectiveness of ethics education offered for engineering students in higher education institutes. As an example on

existing attempts is a recent large-scale study covering engineering undergraduate students from 18 higher education institutes in the U.S [33]. The study aimed to provide descriptive data to aid the process of identifying ethics education practices that most effectively promote ethical development of engineering undergraduates. The data was collected using two main tools; the first is the "Student Engineering Ethical Development (SEED)" survey which was developed by the research team [33]. The survey included 152 items targeting the following measurements: Students' characteristics, ethics related curricular and co-curricular experiences, two constructs of ethical development, which are knowledge of ethics and ethical behavior. The second tool utilized was the Defining Issues Test Version 2 (DIT-2), which is a well-established test used to assess moral judgment/reasoning development [34]. The study has shown that the DIT-2 results are consistent with national norms of DIT-2 measurements. In addition, the authors pointed out that students' knowledge of ethics was 'surprisingly low' [33].

Other studies attempted to use DIT-2 to measure engineering students' moral judgment. A study conducted by May and Luth has utilized DIT-2 in assessing engineering students' moral judgment. They planned this study to investigate the impact of ethics education on enhancing a number of ethical outcomes [35]. Moreover, the authors of the study developed a survey to measure the five remaining outcomes which are: Students' knowledge of responsible conduct of research (RCR) and four positive psychological outcomes including: perspective-taking, moral efficacy, moral courage, and moral meaningfulness. The DIT-2 and survey were conducted in a pre- and post-test experiment design. A main result reported by the authors is that no significant difference was found in students' moral judgment measured by DIT-2 before and after exposure to an ethics course [35]. Drake and others [36] also used DIT-2 to test and compare the effectiveness of two approaches to ethics education by relying on measuring development of moral reasoning in engineering students. The experiment was conducted following a pre- and post-test with a control group experiment design. The experimental group was composed of engineering students where some are exposed to a full course on ethics education and others are exposed to a course with a module on ethics during the semester. As with the previous study, no significant difference was detected in moral reasoning of engineering students before and after exposure to ethics education [36].

Referring back to the discussed studies it can be noticed that moral judgment/reasoning has been widely examined in studies that attempted to measure effectiveness of ethics education for engineering students. Such studies have utilized the well-know DIT test to measure moral reasoning of students. A brief discussion on DIT and DIT-2 test is provided next.

A. DIT-2

The DIT-2 is the second version of the DIT that is widely used to measure individuals' moral reasoning [36]. Moral judgment can be described as "the ability to apply general moral principles to particular situations" [37] it is widely recognized as an important element of ethics education [1], [9], [37]–[38]. The validity of the DIT test has been established by 30 years of testing by many measures, one measure is its sensitivity to the effect of educational interventions [36], [14], [39] cited in [37]. Developers of DIT-2 have provided significant theoretical refinement of the framework underlying the DIT allowing for a more accurate test of moral judgment [37]. The DIT-2 assumes that three moral schemas may be active in the individual's mind in the same time [40] which are; preconventional that can be described as personal narrow interest, conventional characterized as appeal to duty and maintenance of existing social order and postconventional which includes the search for moral ideals and how the ideal social order must be [40]. The test consists of a set of 5 moral dilemmas in social context [33], each stated in one paragraph. Each dilemma is followed by twelve questions corresponding to "different ways to judge what is important for making a decision about the dilemma" [33]. Participants are required to state the importance of each question in taking the decision, and then rank the four most important questions. Reading the test dilemmas and the DIT questions activate moral schemas [40]. When the participant encounters a test question that activates a preferred schema and makes sense, that question is rated and ranked as being of high importance in formulating the moral decision. On the other hand, encountering a question that does not make sense or does not activate a preferred schema, the question receives a low rating [40].

B. DIT-2 in engineering context and the ESIT

Developers of the DIT-2 and other experts in ethics education have identified the usefulness and need for profession-specific assessment tools [41]–[42]. Similar suggestions were reported by Drake et al. [36] deploying the DIT-2 to measure moral reasoning. Based on the test results, no significant difference was detected in moral reasoning of engineering students before and after exposure to a stand-alone ethics course. Similarly, a recent study [35] has found that measuring moral judgment using DIT-2, moral reasoning did not increase as a function of the ethics education conditions. Drake et al. [36] suggested that a general measure of moral judgment such as DIT-2 may not reflect the discipline-specific judgment needed in professional settings such as the case with engineering practice. In a follow up study [37], researchers have hypothesized that these results are due to the fact that DIT-2 tests engineering and science students on general dilemmas that student may not relate to. Borenstein et al. [37] were encouraged to develop The Engineering and Science Issues Test (ESIT) that was designed to follow the structure of DIT-2. A major difference is that the dilemmas in ESIT are drawn from engineering and science contexts rather than a general social context [37]. Such test is assumed to be more sensitive to the impact of professional ethics education on engineering and science students. ESIT was tested by administration to engineering students before and after exposure to a stand-alone course of ethics education. Results have demonstrated significant development in moral reasoning measured by the ESIT due to ethics instruction [37]. The ESIT seems to be a promising tool to measure moral reasoning development for engineering students as pointed out by [35].

VII. Barriers/Constraints that Impede the Effectiveness of Engineering Ethics Education

Integrating engineering ethics into the technical courses of the engineering curriculum is faced by several difficulties and oppositions [43]. Difficulties and oppositions are produced by the teaching faculty, students, the engineering ethics curricula and other constraints. The fact that engineering ethics includes many areas related to attitudes, values and behavior makes it uncomfortable for many engineering faculty members to teach, especially that some

of these values have religious overtones [6]. Also, faculty members feel that they don't have formal training in ethics [43] and they don't possess the background skills and education for teaching ethics [1]. These non-supportive attitudes highly affect the success of ethics delivery to students.

Students identify engineering ethics as a non-quantified area of study, i.e. subjective. They perceive it as the softer side of engineering which in their opinion is less interesting [6]. In addition, concrete and specific concepts are preferred by many engineering students over general and abstract concepts taught in engineering ethics [6]. "Philosophy is not practical" is a common pre-concept the engineering students have. Since engineering ethics is related to philosophy (from the students point of view) they believe that engineering ethics is little useful for the engineering field [6]. What's most difficult is the emotional engagement of the students. Newberry [1] reports that the students end of year surveys returned that the ethics course is the least interesting, least useful, most trivial. They also mentioned that ethics is irrelevant, it is common sense, waste of time and effort when studied. This is considered as a main barrier.

Engineering ethics curricula also impede the effectiveness of the engineering ethics education. Engineering ethics is somehow difficult to integrate with the technical engineering topics [6]. In addition, the engineering curriculum is already overcrowded and there is not enough time to include ethics in [43] [44]. The issue of crowded engineering curriculum has been also a barrier to include other topics and activities for another set of essential skills, such as entrepreneurship [45][46], research based learning [47], meaningful mathematics [48], experiential and project based learning approaches [49] [50], continuous assessment and effective feedback provision [51][52], etc. Other constraints related to time, money, role complexity and potentially conflicting interests and commitments are also noted [43].

VIII. Conclusion

The paper at hand aimed to demonstrate the results of an extensive literature review on engineering ethics and engineering ethics education. It revealed the importance of engineering ethics in the engineering profession. Pedagogical approaches along with the content of these approaches were reviewed ranging from regular, well-established approaches to the more modern approaches utilizing web and computerised resources. Several assessment methods were reviewed and documented. Most of these assessment methods utilized the well-established DIT-2 to measure moral reasoning of students as moral reasoning is a major element targeted by ethics education. The DIT-2 has shown questionable results in assessment of engineering ethics education as it assesses students' moral reasoning in general contexts that may have not been influenced by the engineering ethics education. Thus, the need for a contextualized assessment instrument for the engineering specific settings is noted and resulted in the development of instruments such as the ESIT which has shown promising results. The paper also highlighted barriers impeding the effectiveness of engineering ethics education.

References

[1] B. Newberry, "The dilemma of ethics in engineering education," Science and Engineering Ethics, vol. 10, no. 2, pp. 343–351, 2004.

[2] R. Williams, "Education for the profession formerly known as engineering," The Chronicle of Higher Education, vol. 49, no. 20, pp. 12-13, 2004.

[3] J. Herkert, "Engineering ethics education in the USA: Content, pedagogy and curriculum," European Journal of Engineering Education, vol. 25, no. 4, pp. 303-313, 2000.

[4] A. Colby, and W. Sullivann, "Teaching ethics in undergraduate engineering education," Journal of Engineering Education, vol. 97, no 3, pp. 327–338, 2008.

[5] K. Stephan, "Is engineering ethics optional?," IEEE Technology and Society Magazine, pp. 6-12, 2001/2002.

[6] G. Ermer, and S. VanderLeest. "Using design norms to teach engineering ethics," in ASEE, 2002.

[7] M. Martin, and R. Schinzinger, Ethics in Engineering, McGraw-Hill, New York, 1993.

[8] J. Li, and S. Fu, "A Systematic approach to engineering ethics," Springer Science + Business Media, vol. 18, pp.339–349, 2010.

[9] C. Harris, M. Davis, M. Pritchard, and M. Rabinss, "Engineering ethics: what? why? how? and when?," Journal of Engineering Education, pp.93-96, 1996.

[10] R. Hollander, and C.R. Arenberg, "Ethics education and scientific and engineering research: What's been learned? What should be done?," Summary of a workshop. Retrieved February 6, 2010, from National Academy of Engineering: http://www.nap.edu/catalog.php?record_id=12695.

[11] N. Steneck, "Designing teaching and assessment tools for an integrated engineering ethics curriculum," ASEE/IEEE Frontiers in Education, 1999.

[12] R. Devon, "Towards a social ethics of engineering: the norms of engagement," Journal of Engineering Education, 1999.

[13] S. Illingworth, Supporting Philosophy, Theology, Religious Studies, History of Science and Philosophy of Science. The Higher Education Academy, 2010.

[14] J.R. Rest, D. Narvaez, M.J. Bebeau, and S.J. Postconventional moral thinking: A Neo- Kohlbergian approach. L. Erlbaum Associates, Mahwah, New Jersey, 1999.

[15] M. Rabins, "Teaching engineering ethics to undergraduates: why? what? how?," Science and Engineering Ethics, vol. 4, no. 3, 1998.

[16] M. Dyrud, "Cases for teaching engineering ethics," in ASEE/IEEE Frontiers in Education Conference, 2004.

[17] C. Bertha, "How to teach an engineering ethics course with case studies," American Society for Engineering Education, 2010.

[18] Lynch, and T. William, "Teaching engineering ethics in the united states," IEEE Technology and Society Magazine, vol. 16, no. 4, pp. 27-36, 1997/1998.

[19] J. Lincourt, and R. Johnson, "Ethics training: a genuine dilemma for engineering educators," Science and Engineering Ethics, vol. 10, no. 2, pp.353-358, 2004.

[20] J.A. Cruz, and W. J. Frey, "An effective strategy for integrating ethics across the curriculum in engineering: An ABET 2000 challenge," Science and Engineering Ethics, vol. 9, no. 4, pp. 543–568, 2003.

[21] G.C. Graber, and C.D. Pionke, "A team-taught interdisciplinary approach to engineering ethics," Science and Engineering Ethics, vol. 12, no. 3, pp.313–320, 2006.

[22] H. Zandvoort, G.J. Van Hasselt, and J. A. Bonnet, J.A.B.A. F. Bonnet "A joint venture model of teaching required courses in 'ethics and engineering' to engineering students," European Journal of Engineering Education, vol. 33, no. 2, pp. 187–195.

[23] P. Bowden, "Teaching ethics to engineers – a research based perspective," European Journal of Engineering Education, vol. 35, no. 5, pp. 563–572, 2010.

[24] K. Schmaltz, "Engineering ethics instruction as an integrated professional component," American Society for Engineering Education, 2006.

[25] K. Sugihara, "Developing teaching methods for an engineering ethics curriculum," International Conference on Engineering Education, 2003.

[26] P. Lloyd, and I. de Poel, "Designing games to teach ethics," Science and Engineering Ethics, vol. 14, pp. 433–447, 2008.

[27] W. Carpenter, "Teaching engineering ethics with the engineering ethics challenge game," American Society for Engineering Education, 2005.

[28] M. Loui, "Educational technologies and the teaching of ethics in science and engineering," Science and Engineering Ethics, vol. 11, no. 3, pp. 435-446, 2005.

[29] H. Stern, and P. Russell, "An instructional module for engineering ethics," ASEE/IEEE Frontiers in Education Conference, 2002.

[30] C. Chung, and M. Alfred, "Design, development, and evaluation of an interactive simulator for engineering ethics education (SEEE)" Science and Engineering Ethics, vol. 15, pp. 189–199, 2009.

[31] M.L. Cummings, and J. Lo, "Globalizing engineering ethics education through Web-based instruction," 2004 International Symposium on Technology and Society, pp. 92–95.
[32] Alpay, "The student design of resources for ethics education," WEE, pp.142-146, 2011.
[33] C.J. Finelli, M.A. Holsapple, E. Ra, R.M. Bielby, B.A., Burt, D.D. Carpenter, T.S. Harding, and J.A. Sutkus, "An assessment of engineering students' curricular and co-curricular experiences and their ethical development," Journal of Engineering Education, vol. 101, no. 3, pp. 469–494, 2012.
[34] J. R. Rest, D. Narvaez, S. J. Thoma, & M. J. Bebeau, "DIT2: Devising and testing a revised instrument of moral judgment," Journal of Educational Psychology, vol. 91, no. 4, pp. 644–659, 1999.
[35] D.R. May, and M.T. Luth , 'The effectiveness of ethics education: a quasi-experimental field study," Science and Engineering Ethics, pp. 1-24, 2012.
[36] M. Drake, P. Griffin, R. Kirkman, and J. Swann, "Engineering ethical curricula: assessment and comparison of two approaches," Journal of Engineering Education, vol. 94, no. 2, pp. 223–231, 2005.
[37] J. Borenstein, M.J. Drake, R. Kirkman, and J.L. Swann, "The Engineering and Science Issues Test (ESIT): a discipline-specific approach to assessing moral judgment," Science and Engineering Ethics, vol. 16, no. 2, pp. 387–40, 2010.
[38] D. Narvaez , and J. Rest, "The four components of acting morally," in Moral Behavior and Moral Development: An Introduction, W. Kurtines, and J. Gewirtz, Eds, McGraw-Hill, New York, 1995.
[39] D. J. Self, and E.M. Ellison, "Teaching engineering ethics: Assessment of its influence on moral reasoning skills," Journal of Engineering Education, vol. 87, no. 1, pp. 29–34, 1998.
[40] J.R. Rest, D. Narvaez, S.J. Thoma, and M.J. Bebeau, "A Neo-Kohlbergian approach to morality research' Journal of Moral Education," vol. 29, no. 4, pp. 381-395, 2000.
[41] M.J. Bebeau, "The defining issues test and the four component model: Contributions to professional education," Journal of Moral Education, vol. 31, pp. 271–295, 2002.
[42] J. Rest, and D. Narvaez, (eds), Moral development in the professions: Psychology and applied ethics. Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1994.
[43] S. Bird, and J. Sieber, "Teaching ethics in science and engineering: effective online education," Science and Engineering Ethics, vol. 11, no. 3, 2005.
[44] Khraisheh, M, Kahraman R, Romanowski, M, and Abdulwahed M, 2013. Integrating the Ethics in the Chemical Engineering Curriculum: The Qatar University experience. Interdisciplinary Engineering Design Education Conference (IEDEC), 2013 3rd , vol., no., pp.112,114, 4-5
[45] M. Abdulwahed, J. Abu Hamad, M. Hasanain, M. O. Hasna, "Entrepreneurship Education in Engineering: A Literature Review, and an Integrated Embedment Proposal", Recent Advances in Educational Methods , WSEAS Press, Cambridge, UK, pp. 106 – 111, 2013.
[46] M. Hasanain, M. Abdulwahed, and Q. Malluhi, "Entrepreneurship for Engineering Students: A Course Development, Teaching, and Impact Assessment", In Proceedings of the IEEE International Conference on Teachings, Assessment, and Learning for Engineering (TALE), 26-29 August, Balid, Indonesia.
[47] M. Abdulwahed, K. Shaban, "Research Based Learning in Computing Courses for Senior Engineering Students," In Proceedings of the IEEE International Conference on Teachings, Assessment, and Learning for Engineering (TALE), 20-23 August, 2012, Hong Kong
[48] M. Abdulwahed, B. Jaworski, A. R. Crawford, "Innovative approaches to teaching mathematics in higher education: a review and critique," Nordic Studies in Mathematics Education, 2012, 17(2), 49–68.
[49] M. Abdulwahed, Z. K. Nagy, R. Blanchard, "The TriLab, a Novel View of Laboratory Education," International conference on innovation, good practice and research in engineering education, EE2008, Engineering Subject Centre, Loughborough, UK, 14-16 July 2008.
[50] M. Abdulwahed, Z. K. Nagy, R. Blanchard, "Constructivist Project Based Learning Design, a Cybernetics Approach," Journal of Education, Information and Cybernetics, 1(2), 2009, pp 1-8, ISSN 1943-7978
[51] M. Abdulwahed, Z. K. Nagy, "A Control Systems Engineering Approach to Designing an Effective Lecturing Model: The Implication of Feedback and Self-Construction of Knowledge," In Innovations 2012: World Innovations in Engineering Education and Research, ed. W. Aung, et al., iNEER, Potomac, MD, USA, 2012, pp. 29-48.
[52] M. Abdulwahed, W. Balid, "Systems and Cybernetics Modelling of Self-Regulated Learning: Analysis and Implications," Recent Advances in Educational Methods , WSEAS Press, Cambridge, UK, pp. 100 – 105, 2013.