Roadmap for Industrial Engineering Education Sustainability

Hani Shafeek1,2,*

1Department of Industrial & Systems Engineering, Faculty of Engineering, University of Jeddah, Jeddah, 21959, Saudi Arabia
2Faculty of Technology and Industrial Education, Suez University, Suez, 41522, Egypt

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A B S T R A C T
In industrial engineering education the possibility links are not easy between renewal and sustainability processes, particularly when renewal is encouraged irrespective of sustainability. This paper aims to explore sustainability frameworks to better understand and improve the effectiveness of industrial engineering education change processes towards sustainability in universities. This work describes a sustainable process developed for the continuous improvement of a Bachelor of Science in Industrial Engineering (BSIE) program. The objective is to apply the results of the student outcome assessment and their evaluation to improve the program. The methodology taken in this work is implementation of a roadmap for sustainable development built around existing findings in literature, higher education case studies, and chosen sustainable development practices. Satisfaction of the various stakeholders was achieved and year-on-year improvement in the achievement of the student outcomes was observed by following the sustainable development roadmap. This study focuses on the sustainability of undergraduate industrial engineering programs only. The recommendations suggested at the end of each academic year are feasible and practical for implementation in the next year by all faculty and staff members in order to close the loop for a sustainable development cycle. The results of this study can be useful for transition from traditional IE education to applied IE Education. This work also describes how the concept of sustainability can be part of an IE department, adapting the philosophy of sustainable development.

1. Introduction

Sustainability is no longer an optional activity but has become a basic requirement to keep pace with rapid technological development. In academia these efforts include the program itself as well as the staff members [1], administrators, students and workplace. Transitioning engineering education - industrial engineering in particular - from traditional to sustainable includes all factors including social and environmental and economic as discussed by [2]. To address this issue, both internal and external audiences must focus on the nature of the real area, by revising the IE education program to concentrate on the concept [3], [4] of sustainability. Concern of sustainability has strong emotional resonance of the environment [5]-[10], program learning outcomes as well as students’ skills [11], [12].

Applying concepts of sustainability to the campus and program gives students an impactful way to deepen their commitment to sustainability by using the campus as living learning lab to help the waste prevention goals. Students can open doors difficult for staff to open [13] and bring valuable ideas to change process that the staff can force it into action. The sustainability across the curriculum circle focuses on one topic only: curriculum. The circle has investigated sustainability learning outcomes and discussing how to engage students in sustainability. An effective IE department can create a shift in compos that is basic to transformative sustainability. Implementing one item of sustainability on campus[14] can happen quickly but creating a culture of sustainability needs a long time. The learning outcomes focus define sustainability in terms of its past, present and future initiatives. Demonstrate change-agent skills and knowledge so that the students can implement viable solutions to shift department, cultural practices and policies toward sustainability.

IE department trusts it is highly important to help close today’s tech skills gap [15]. It puts technology at the core of IE curricula [16]. Also, it takes into account teaching approach, program’s
goals, objectives and student outcomes [17] and helps IE undergraduate students stand out with the right skills employers require. The recent IE engineer should include a firm background in the sciences, math and engineering practice [18]. Nobody can expect to improve engineers exclusive of such consideration. IE Engineers must extremely appreciate the role they play in industry service, mainly in their professional ethics [19] and responsibilities. The IE department is faithful to integrating technology into all educational programs to improve educational quality [20], learning and teaching.

An outline of the characteristic passageway of IE program review to become ABET-accredited is described. Accreditation reflects reaching and assurance in learning and teaching and is a signal of quality for students, workplace and staff. The continuing IE education initial accreditation process has three steps. The first step is the application process, initial screening to determine whether IE department qualifies as an accredited continuing IE education provider. Second, the survey process for on-site survey is scheduled and activity documented. The final step is the decision when the surveyor completes assessment and submits findings to the clarity committee on continuing improvement. The ABET committee makes all accreditation decisions. IE Engineering conducts outcome assessment [21].

To examine students’ academic setting, valuable teaching methods, continued improvements, and to guarantee conformity with accreditation standards. The most important process of education measurements are outcome measures, balance measures, and process measures. IE department should evaluate the learning outcomes to complete the performance gauge.

From previous literature review the most common challenge which faced sustainability of engineering education [22] is trouble in transmitting the idea of sustainability [23], [24] Events and models submitted focus wholly on environmental issues [25]. Combining disciplines for the teaching of sustainability appears to be a problem [26]. Sustainable subjects are discussed only in certain fields in a narrow area [27]. Lecturers are not trained to sustainability models [28], [29]. There is a shortage of useful and real patterns of how sustainability can be inserted in the particular framework of the course. [30] There is a shortage of events that promote students to develop sustainable behaviours. [31], [32]. Also, there is a shortage of encouragement from the institution’s top management for the promotion of social tasks that consider local communities [29], [33]. In the facilities of the faculty, the concepts of sustainability are not used [27], [34], [35]. Lecturers lack attention to topics attached to sustainability [36].

The ABET program assesses student progress on the outcomes in the core courses of the program curriculum, generally gathering data on three or four ABET Criterion Student Outcomes (SO) per course. The program also periodically re-evaluates the Criterion 2 Program Educational Objectives (PEO) and how graduates show that they are meeting them using the SO assessment process. The BSIE program had a good balance of data collection practices in place.

This paper explains what went into the process of developing plans for a consistent and defined review process for both PEOs and SOs.

Previous studies have proposed sustainability education engineering such as [15]-[17], [21], [24], [37], [38]. However, such work has not yet been proposed to novelty assessment of the processes followed method. The practices criteria IE education engineering outcomes are dependent not only on inputs such as supervisors, students, times and etc., but also on the processes followed by industrial engineering department to convert inputs into defined outcome. Assessment and evaluation education process is carried out through (measuring performance level, identifying weakness and formulating of action plan), starting with direct assessment, i.e., of coursework and followed by indirect assessment such as the following: industrial advisory committee feedback, students’ survey, exit survey, alumni feedback, employer feedback and faculty course report.

The results of this industrial engineering education sustainability indicate that, as compared to previous studies methods, the refined method better reflects the novelty assessment by experienced industrial engineering staff.

Henceforth, the study is arranged as follows. Part 2 introduces the BSIE program background, the program’s educational objectives (PEOs), and student outcomes, and shows how they are related. Next, part 3 introduces how the assessment and evaluation of student outcomes is systematically conducted followed by a description of the sustainable continuous improvement strategy. Finally, part 4 provides the conclusions.

2. Student Outcomes and Program Educational Objectives

IE objective was to meet the need in vicinities for well-trained industrial engineers capable of designing, installing, maintaining, and managing complex industrial operations and manufacturing systems in order to be competitive in the regional and global environment.

2.1. Program Educational Objectives

The BSIE program has a set of objectives that translates the mission of the program into measurable and defined tasks.

After few years of graduation, graduates of the BSIE program will:

- Positively impact work environments at IE related challenging positions in the industry or have successfully established startups.
- Continually develop their knowledge and adapt to evolving professional environments through career development and/or graduate level advanced studies and research.
- Be committed to serving local, regional, and/or professional communities through knowledge development and innovation while functioning ethically.

The BSIE PEOs provide the link between the program and the mission of the institution as well as between the program and the needs of stakeholders. The BSIE educational processes are planned and organized to ensure that the PEOs can be achieved. These educational processes include the means to develop, deliver, evaluate, and improve the quality of BSIE graduates several years after graduation and hence meet program objectives.
2.2. Student Outcomes

The BSIE Program adopted the ABET a-k general criteria student outcomes.

- An ability to apply knowledge of mathematics, science, and engineering;
- An ability to design and conduct experiments, as well as to analyze and interpret data;
- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
- An ability to function on multidisciplinary teams;
- An ability to identify, formulate, and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- A recognition of the need for, and an ability to engage in lifelong learning;
- A knowledge of contemporary issues; and
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

2.3. Relation between Program Educational Objectives and Student Outcomes

Each student outcome is assessed within the academic program. Achievement of SOs can lead to the achievement of the PEOs and are a necessary condition for achieving the PEOs. The results of SOs evaluation will be applied to improve IE program.

Table 1 presents the BSIE Student Outcomes versus Program Educational Objectives. As stated above, the student outcomes (SOs) can help achieve the program educational objectives (PEOs) by producing graduates who will be able to practice the necessary industrial engineering skills. These graduates are expected to have the ability to apply knowledge, techniques, skills, and modern tools, mathematics, chemistry, physics, engineering, and technology, analyze and conduct experiments, design and implement processes and systems (to solve industrial engineering problems), and efficiently communicate (written, oral, and graphical communication). Further, they will develop professional and ethical responsibilities.

3. Sustainable Development

Sustainable education is not a magical word that contains a simple solution to all of the problems with engineering education. It is only the definition of an ideology that contains practical solutions. Sustainability principles can apply at all scales. The methodology followed for sustainability implementation in industrial engineering education was through the utilization of ABET criteria. When new quality requirements emerged, an enhanced curriculum that incorporates the ABET requirements was introduced. The ABET requirements necessitated activities to assess sustainability. When the sustainability principles were put in place, significant improvements were made, as the process was simplified and made easier for instructors to comply with the requirements thereof. As a result, the faculty members became more familiar with the sustainability assessment process.

3.1. Review Process of Program Educational Objectives

The process used to periodically review the PEOs so that they stay stable with the university mission, the different constituents’ needs, and the ABET Engineering Accreditation Commission (EAC) criteria are as follows:

(1) The Sustainability Committee reviews the PEOs and may makes a draft for a new program educational objectives (PEOs) if any of the following conditions arises:
- A change in the University mission.
- A request for change coming from members of one or more of the program’s main constituencies.
- A change in the ABET Inc. EAC criteria affecting the PEOs.
- A change in the vision of national and international professional societies regarding engineering practice.

(2) Based on the new PEOs draft, the Department Council recommends some changes.

(3) The Department seeks the opinion of the program’s main constituencies as follows:
- The Program Advisory Committee meets and reviews the program educational objectives. After discussion, they
respond to a survey questionnaire and suggest further improvement.

- The Department meets with representatives from the main employers of the industrial engineering graduates and reviews the program educational objectives (PEOs) in relation to employers’ needs. The purpose is to discuss how to make the proposed PEOs compatible with the employers’ needs. Then, the employers are asked to complete the PEOs survey forms and provide their comments on how to improve the program.

- The Sustainability Committee sends surveys to the alumni, inviting their feedback on the adequacy of the PEOs.

(4) The Sustainability Committee statistically analyzes the inputs from the constituencies and accordingly produces a new PEOs draft.

(5) The Department Council discusses the proposed new version of the PEOs, and, if approved, publishes it in the program’s website, brochure, bulletin, etc.

3.2. Assessment and Evaluation of Student Outcomes

Assessment is intended to enable high-performance IE student learning systems through continuous measurement of processes and outcomes. Assessment practices within each institution and IE program vary in levels of success. Identifying and understanding the fears that faculty hold are steps toward creating a climate of success. The reality is that the adoption of change and innovation is a process that proceeds from individual to individual. Assessment methods may be too complex, cumbersome, or time-consuming to maintain over time or obtain the direct assessment of desired outcomes.

Faculty of engineering must be given the knowledge and professional development to break the inertia, to become informed about the real benefit of accountability through assessment. Practical barriers may include emphasis on planning learning activities rather than outcomes that might result, a reluctance to change established current practice, the difficulty of specifying the meaningful criteria by which to rate student work, the need for training and ongoing support, the lack of a plan for developing and implementing assessment over long term, and simply a lack of time for planning and implementing assessment.

Effecting change requires simultaneously affecting both individual and collective behaviors. Strategies for change depend on the levels of resistance, for example, level one: resisting the idea itself; level two: resisting the change because of deeper emotional issues; and level three: resisting because of deeply embedded perspectives and distrust.

Formative assessments that can be used for program improvement are concept inventories, reflective journals, portfolios and concept map. For formative program assessment to be effective, the most important lesson to remember is that those who will benefit from information (student, faculty, and course coordinators) must receive it in a timely and meaningful way in order for this to happen.

Summative assessment, on the other hand, is used to test the scale of learning after the program ends.

The assessment, evaluation and feedback to the continuous improvement of the program undergo the following three steps:

- Assessment tools of the SOs - both direct and indirect.
- Direct assessment of SOs is usually based on the coursework and indirect assessment of SOs is carried out through surveys.
- This step analyzes and compares the data to a pre-set performance indicator, which forms the evaluation process.
- Checking the degree to which the data evaluation meets the pre-set targets is central to the continuous improvement process.

Figure 1 below is a summary of these sustainable processes.

![Figure 1: Sustainability: elements of process improvement](image)

The process consists of the following chronological steps:

- After a long and careful consideration or discussion, and arrival at a common understanding of each of the individual SO’s, the faculty members, staff and students determined that knowledge, skills, attitudes, and motivation were the 4 major competencies necessary for achieving these SOs.
- KPIs (i.e., the rubrics) that best represent the requirement of each of the SOs were identified and saved in a data file for use in assessment as necessary.
- Each course syllabus sought to identify three or four major SOs.
- All core courses of the program followed Step 3 above. The matrix mapping the courses and the SOs is illustrated in Table 2.
- Assessment of the first yearly cycle for all core courses, their results, and samples of student work are available in course portfolios.

After extensive deliberations, the matrix for BSIE core courses was mapped to the ABET student outcomes shown in Table 2 was finalized. The SO mapping matrix shows that at least three core courses of the program targeted each of a-k SOs.

3.2.1. Direct Assessment

Quizzes, exams, projects, presentations, homework, etc., where the achievements were directly tied to program outcomes, formed the assessment of the student outcomes (SOs). The assessment was conducted every time a course was taught.

The direct assessment of a core course, say IEN 422, is now discussed. The faculty member who was the instructor of this course adhered to the mapping of the course to the SOs, presented in Table 2. Table 3 below presents the various assessment tools and their relative weights chosen by the course instructor, while Table 4 displays students’ actual achievements in this particular course.

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Table 2: Student Outcomes Mapping

| Course Code | Course Title                          | A | B | C | d | e | f | g | h | i | j | k |
|-------------|--------------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|
| IEN 256     | Engineering Management               |   | Δ |   |   | Δ |   |   | Δ |   |   |   | Δ |
| IEN 311     | Operations Research I                | Δ | Δ |   |   |   |   |   |   |   |   |   | Δ |
| IEN 322     | Computer Programming for IE          | Δ | Δ | Δ |   |   |   |   |   |   |   |   |   |
| IEN 323     | System Analysis and Design           | Δ |   |   |   |   |   |   | Δ | Δ | Δ |   |   |
| IEN 331     | Engineering Prob. & Statistics       | Δ | Δ | Δ |   |   |   |   |   |   |   |   |   |
| IEN 341     | Work Study                           | Δ | Δ |   |   |   |   |   |   |   |   |   | Δ |
| IEN 342     | Human Factors Engineering            | Δ | Δ |   |   |   |   |   | Δ |   |   |   |   |
| IEN 361     | Manufacturing Processes I            | Δ | Δ |   |   |   |   |   |   | Δ | Δ |   | Δ |
| IEN 363     | Manufacturing Systems Design         | Δ | Δ |   |   |   |   |   |   | Δ | Δ |   | Δ |
| IEN 421     | Industrial Information System        | Δ |   | Δ | Δ | Δ |   |   |   |   |   |   |   |
| IEN 422     | Industrial Systems Simulation        | Δ | Δ | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 431     | Industrial Quality Control           | Δ | Δ | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 432     | Design of Experiments                | Δ | Δ | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 451     | Production Planning and Control      | Δ | Δ | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 453     | Facilities Planning and Design       | Δ | Δ | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 482     | Intro to Entrepreneurship            | X | X | Δ | Δ | Δ |   |   |   |   |   |   | Δ |
| IEN 498     | Senior Project I                     | Δ | Δ | X |   |   |   |   | Δ | Δ | Δ | Δ | Δ |
| IEN 499     | Senior Project II                    | Δ | Δ | Δ | Δ | Δ | Δ | Δ | Δ | Δ | Δ | Δ | Δ |

The polar graph in Figure 4-2 below illustrates the results tabulated in Table 4-3. It shows the degree of attainment of course outcomes b, e and k, indicated by the red lines and compared with the targeted attainment level of 70% (the inner border of the blue colored area). As is clearly indicated, of the three outcomes, b and e just about surpassed the targeted level while outcome k had a satisfactory achievement of 78%.

The same process of direct assessment of course IEN 422 was applied to all core courses offered in the academic year and the achievement levels were collected and graphically displayed as a polar graph in Figure 3. The outcomes that had the lowest achievement were noted and appropriate recommendations were made for improvement. These recommendations were implemented in the subsequent academic year. Figures 4 and 5 show continuous improvement of the program from 2016-2019.

Table 3: Assessment Tools for IEN 422 Course

<table>
<thead>
<tr>
<th>Assessment Tools</th>
<th>b</th>
<th>e</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>2.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Exercises</td>
<td>7.0</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Quizzes</td>
<td>6.5</td>
<td>2.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Mid-Term 01</td>
<td>6.0</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Mid-Term 02</td>
<td>3.0</td>
<td>10.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Project Presentation</td>
<td>5.0</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Project Report</td>
<td>30.0</td>
<td>30.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Table 4: Assessment Achievement for the IEN 422 Course

<table>
<thead>
<tr>
<th>Assessment Tools</th>
<th>b</th>
<th>e</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>2.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Exercises</td>
<td>4.5</td>
<td>0.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Quizzes</td>
<td>3.6</td>
<td>1.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Mid-Term 01</td>
<td>4.5</td>
<td>0.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Mid-Term 02</td>
<td>3.0</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Project Presentation</td>
<td>5.0</td>
<td>8.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Project Report</td>
<td>21.2</td>
<td>22.0</td>
<td>31.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Achievement Type</th>
<th>b</th>
<th>e</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Achievement</td>
<td>21.2</td>
<td>22.0</td>
<td>31.2</td>
</tr>
<tr>
<td>Targeted Achievement</td>
<td>30.0</td>
<td>30.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Percentage of Achievement</td>
<td>71%</td>
<td>73%</td>
<td>78%</td>
</tr>
</tbody>
</table>

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3.2.2. Indirect Assessment

Performance targets defined the targeted level of attainment in order to guide the evaluation of survey data. Table 5 presents the tools for the indirect assessment and evaluation of SO, frequency of the assessment, assessment approach and the expected level of attainment.

<table>
<thead>
<tr>
<th>Assessment Tool</th>
<th>Frequency of Assessment</th>
<th>Assessment Approach</th>
<th>Expected Level of Attainment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Surveys</td>
<td>Semester</td>
<td>Indirect</td>
<td>70%</td>
</tr>
<tr>
<td>Exit Survey</td>
<td>Semester</td>
<td>Indirect</td>
<td>70%</td>
</tr>
<tr>
<td>Faculty Course Report</td>
<td>Semester</td>
<td>Indirect</td>
<td>70%</td>
</tr>
<tr>
<td>Industrial Advisory Committee Feedback</td>
<td>Annual</td>
<td>Indirect</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Polar charts similar to Figure 3 were generated for each of the indirect assessment tools as a visual tool in making appropriate recommendations for continuous improvement of the student outcomes.

3.3. Sustainable Continuous Improvement Strategy

A continuous improvement strategy of closing the loop was developed by the Sustainability Committee. The process, depicted in figure 4, starts with deciding on the desired attainment level of the student outcomes at both the program and course levels. The educational process throughout the fall and spring semesters measures the actual attainment level of the student outcomes via assessment and evaluation, both direct and indirect. The comparison of the desired and actual attainment levels of the SOs is discussed in the annual academic report prepared at the end of each academic year consolidating both semesters. Performance and weakness evaluation are, then, performed by industrial advisory committee as well as by the department and faculty committees. The next step is the formulation of actions plans and strategies for improvement in the next academic year.

Except for the Industrial Advisory Committee feedback which is received annually, assessment and evaluation are conducted at the end of every semester. The Sustainability Committee reviews
and discusses the comments and feedback. Thus, areas of strength and improvement are identified, and actions are decided on. Both tabular and graphical formats are utilized for the purpose of comparison of direct and indirect assessments of the results of two academic years. Figure 5 is a comparison of SO achievement by direct assessment for 2014-15 vs. 2015-16. Similar comparisons are made for the various indirect assessment tools.

Student Outcomes (SO) that fell below the satisfactory attainment level of 70% as well as those that had the lowest achievement level despite just making the benchmark, were noted for improvement. The IE program made some recommendations for the next academic year in order to improve the attainment levels of these outcomes. Table 6 below lists these recommendations.

Outcome ‘e’

The outcome ‘e’ was targeted by 12 core courses of the program. The average achievement level of the outcome ‘e’ was just above the benchmark level of 70%, because of which the Sustainability Committee suggested some action plans reserved for the next academic year, to improve on the achievement level of the students pertinent to the outcome ‘e’ as shown below in the tabular form.

- Achievement of SO ‘e’ by the Program: 71.17%

<table>
<thead>
<tr>
<th>Contributing Courses</th>
<th>IEN 256, 311, 322, 331, 363, 422, 431, 432, 451, 453, 498, 499</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendations</td>
<td>1. Frequently organize interactive sessions with the students.</td>
</tr>
<tr>
<td></td>
<td>2. Organize field visits to local industries to give them an understanding of the subject matter relevant to the course.</td>
</tr>
<tr>
<td></td>
<td>3. Lay special focus on the weak students by figuring them out at the beginning of a semester through their last semester’s CGPA.</td>
</tr>
<tr>
<td></td>
<td>4. Encourage each student’s participation in the classroom by randomly asking conceptual questions to them. This will generate interest in them towards that particular course.</td>
</tr>
<tr>
<td></td>
<td>5. Incorporate animations and/or videos on selected topics to elucidate knotty points, in order to make students understand easily and appreciate the concept.</td>
</tr>
<tr>
<td></td>
<td>6. Develop students’ reading skills/strategies (skimming and scanning) to tackle textbooks and reference books and solve extra problems as well. Strongly encourage note-taking in class and monitor their notebooks regularly.</td>
</tr>
</tbody>
</table>

Further analysis of the achievement of the outcome ‘e’ during the whole academic year is done below, by plotting the outcome ‘e’ attainment levels of each of the courses targeting the said outcome. This is depicted below in Figure 6. A close analysis of the figure reveals that the attainment levels of the outcome varies from one course to another, to a varying degree. In some courses, the outcome attainment level was relatively lower than the other courses. The faculty teaching a particular course took notice of this and accordingly proposed an action plan for each individual course, recorded and presented in the form of a Course Report included in the course file. A marginal variation in a particular outcome attainment level between the different courses is quite natural and acceptable due to the possibility of slight differences in the assessment style/methods of distinguished faculties.

Figure 7: Graphical Comparison of the Student Outcomes Achievement Using Direct Assessment

Figure 8: Achievement of Outcome ‘e’ in the courses offered during the academic year

Outcome a:

The outcome ‘a’ was targeted by 10 core courses of the department. The average achievement level of the outcome ‘a’ was slightly above the benchmark level of 70% but the achievement level fell from its level in the previous academic year, because of which the Sustainability Committee suggested some action plans proposed for the next academic year, to improve on the achievement level of the students pertinent to the outcome ‘a’ as shown in table below.

- Achievement of SO ‘a’ by the Program: 73.04%
Further analysis of the achievement of the outcome ‘a’ during the whole academic year is done below, by plotting the outcome ‘a’ attainment levels of each of the courses targeting the said outcome. This is depicted below in Figure 7. A close analysis of the figure reveals that the attainment levels of the outcome varies from one course to another, to a varying degree. In IEN 331 and IEN 361, the outcome attainment levels were extremely low which was the reason for the drop in the average achievement of the outcome. The faculty teaching these particular courses took notice of this and accordingly proposed an action plan recorded and presented in the form of a Course Report included in the course file.

### Outcome k

The outcome ‘k’ was targeted by 10 core courses, as listed below in the table. The average achievement level of the outcome ‘k’ was above the benchmark level of 70% but there was a considerable drop (nearly 10%) in the achievement from 83.34% in 2014-15 to 73.75% in 2015-16, because of which the Sustainability Committee suggested some action plans proposed for the next academic year, to improve on the achievement level of the students pertinent to the outcome ‘k’ as tabulated below.

- Achievement of SO ‘k’ by the Program: 73.75%

Table 7: Recommendations for Improvement of the Students Outcomes Based on Direct Assessment

<table>
<thead>
<tr>
<th>Contributing Courses</th>
<th>Outcome k</th>
</tr>
</thead>
</table>
| IEN 311, 322, 331, 341, 342, 361, 363, 431, 451, 453 | 1. Identify the weaker students in class in order to focus on them.  
2. Encourage each student’s participation in the classroom by randomly asking basic questions to them. This will generate interest in them towards that particular course.  
3. In lectures and tutorials, give students practice in basic conceptual problems, as often as possible.  
4. Develop students’ reading and note-taking skills to maximize learning from textbooks and lectures. Monitor their notebooks regularly. This will enthuse their liking towards knowing the fundamentals of every concept and at the same time develop their reading comprehension. |

Further analysis of the achievement of the outcome ‘k’ during the whole academic year is done below, by plotting the outcome ‘k’ attainment levels of each of the courses targeting the said outcome. This is depicted below in Figure 8. A close analysis of the figure reveals that the attainment levels of the outcome varies from one course to another, to a varying degree. In IEN 311 the outcome attainment level was extremely low. Also, in IEN 422, the achievement level was below the targeted level of 70%. These were the main reasons for the drop in the overall achievement of the outcome as compared to the previous year. The faculty teaching these particular courses took notice of this and accordingly proposed an action plan recorded and presented in the form of a Course Report included in the course file.

![Figure 8: Achievement of Outcome ‘k’ in the courses offered during the academic year](image)

Table 8: Recommendations for Improvement of the Students Outcomes Based on Direct Assessment

<table>
<thead>
<tr>
<th>Contributing Courses</th>
<th>Outcome k</th>
</tr>
</thead>
</table>
| IEN 256, 311, 323, 341, 361, 363, 422, 431, 432, 499 | 1. Students must be made aware of the importance and benefits of having familiarity with modern engineering tools.  
2. Special attention must be given to the weak students by identifying them at the beginning of each semester by assigning all students a nominal project on a topic in the first two weeks of the semester.  
3. Give students hands-on experience, and arrange special supplementary monthly practice sessions so they can use relevant modern engineering tools efficiently.  
4. Assign multiple projects that require the application of these techniques and skills. |

Hence, the Sustainability Committee reassessed, analyzed and then adopted the above recommendations to be implemented in the next academic year specifically targeted to improve the performance of the students pertinent to outcomes ‘a’, ‘e’ and ‘k’.

Based on experience in capstone course teaching, review of the senior project literature [39]-[42] and feedback from senior IE students and senior project supervisors staff, the sum of specific recommendations are presented in the Figure 9. These best practices and criteria for senior project selection are outlined in this work to address the gaps of capstone course from traditional to applied, as new trends in engineering education.

The senior project outcomes are dependent not only on inputs from supervisors, students, times, etc., but also on the processes...
followed by IE department to convert inputs into defined outcomes. We find that lack of hard skills and technical knowledge is not often the cause. More often the causes include lack of soft skills such as communication skills, team work skills, technical writing report skills, and problem-solving skills. We recommended focusing on these soft skills through active learning courses such as introduction to engineering design to improve creative thinking and problem-solving skills for the first-year students’ projects group or team. Culture of capstone team must improve to support team work and encourage the team to select a team leader to manage the team work during the two semesters. The senior project course work conflict should be avoided by teaching this course in the evening, if possible.

We recommended using the five steps of the problem-solving heuristic: define the problem, generate the solution, decide course of action, implement the selected solution and evaluate the solution [43]. Also, we recommended implementation and assessment of all capstone ABET criteria. Students must train to prepare the final senior project product such as a technical report, multimedia presentations, posters, according to meetings of minutes, and explain all evaluation criteria. The project is evaluated by exam committee which consists of three staff members; one of them is the senior/capstone project advisor. Evaluation criteria must be distributed to students with the first day material.

![Figure 11: The capstone course from traditional to applied as new trends in industrial engineering education](image)

4. Conclusion

This paper described a sustainable process, developed and utilized by the BSIE program, to meet the quality standards of the profession for which it prepares IE graduates. The main objective of this paper is to present sustainability approaches developed and implemented to deliver sustainable engineering education to undergraduate students in industrial engineering. This roadmap explained step by step the sustainability element of process improvement. Various assessment and evaluation tools for sustainable improvement were used and described in this paper. The BSIE program has been committed to yearly assessment and evaluation as part of its development and improvement activities. Satisfaction of the various stakeholders was achieved and year-on-year improvement in the achievement of the student outcomes was observed. As a result of the academic evaluation carried out every semester such activities [i.e., yearly assessment and evaluation] became more noticeable or prominent in the programs’ taught courses. The instructors decided on the Learning Outcomes (LOs) for their courses, determined the students’ achievement at the end of the courses and recommended improvement. Further, several surveys were conducted and feedback from both the students and the staff was gathered.

Finally, the department’s Quality and Development Committee maintained and consistently reviewed hard copies of students’ work so as to help enhance the quality of courses and teaching methods. Future work will focus on sustainability of graduate industrial engineering programs with possible extension to sustainable engineering education in general.

References


