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Quality Improvement Using a Stage Gate Approach in Engineering Programmes and Courses

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Abstract

This evidence-based practice paper proposes a framework for quality improvements in program and course design, development, deployment and evaluation and its application at the course level. The proposed framework integrates stage gate approach of new product development with ADDIE (Analyze, Design, Develop, Implement, Evaluate) instructional design model. The paper reports the application of stage gate for a course, aimed at course refinement and attempts to present evidence to assess the effectiveness and achievement of the desired outcomes. Improvements in the course contents, delivery methods, assessments, and student performance are reported for the selected freshmen course titled "Introduction to Engineering". The paper explains activities, working team and deliverables that are part of the stages, with samples. The decision-making methodology in gate reviews using criteria and rubrics are also explained with samples. Samples of course design outputs, course material, checklists with rubrics that were used during the gate reviews also are included in the paper.

1. Introduction

The Fourth United Nations, Sustainable Development Goal (UN SDG) on "Quality Education" targets in its third target (4.3), by 2030, equal access for all women and men to affordable and **quality technical, vocational, and tertiary education**, including university [1]. While engineering education needs to be contemporary in order to achieve the SDG, the current engineering education has large gaps to bridge in the Indian context. Post the economic reforms beginning in the early nineties, the enrolment to engineering education in India has increased rapidly to 1.7 million in 2017-18 [2]. Engineering institutions have mushroomed without adequate infrastructure, effective governance and good faculty, resulting in poor quality of education. The All India Council for Technical Education (AICTE), set up the National Board of Accreditation (NBA) to assess the quality of programs offered by engineering institutions in India. NBA has made it mandatory for engineering institutions to adapt an Outcome Based Education (OBE) framework for their curriculum design, delivery and assessment. Around 2400 undergraduate engineering programs had accreditation from NBA in 2020 (one third of the total number of engineering and technology programs in the country) [3]. The rejection rate in the accreditation of engineering programs in 2019 was around 20% as reported in the annual report of 2019 by NBA [4]. AICTE mandates various reforms at the macro level. For example, it stresses on addressing graduate attributes of the Washington Accord in assessments [5]. There are other initiatives like Technical Education Quality Improvement Program (TEQIP) as well. A third-party evaluation of the 196 institutions being funded by TEQIP in 2019 reported that, all the significant changes implemented through TEQIP-III require a plan for sustenance, which was missing in most of the institutes [6].

Accreditation, assessment reforms, TEQIP and many similar initiatives have been recommended at a macro level for governance by the statutory bodies associated with engineering education in India. While the macro level reforms are designed to address the career and life prospects of students in engineering education, the review systems at the program level and course level for checking and improving the implementation of reforms and policies are weak. Reviews do not involve industries, alumni etc. to the extent required.

Industry representatives have a limited and time constrained role in reviews which happen during mandated statutory meetings, such as the board of studies, program assessment committee, academic council, etc. The requirements of the industries which can be articulated only by persons representing industries in India, due to the huge divide between industries and institutions, are often not captured and acted upon by programs and institutions. Innovative measures of involving with the industries and proactively working on improvements in programs is essential for quality improvement [7]. Involving the industries is resource intensive and many institutions shy away from it. Hence at the grassroot level, innovation and reform does not happen. Accreditation is periodic and the checks and balances of the current system do not capture these efforts at the grassroot level.

A rigorous process in program and course design, development, deployment and evaluation involving key stakeholders especially representing the industries is required for improving the quality of engineering education in India. This evidence-based practice paper proposes a framework for program and course design, development, deployment and evaluation using the integration of a stage gate approach of new product development with ADDIE instructional design model. It reports the application of the stage gate process to a freshmen course named "Introduction to Engineering", aimed at course refinement and attempts to present evidence to assess the effectiveness and achievement of the desired outcomes.

The authors are engaged in understanding and deploying OBE in a few institutions, at the program and course level for almost a decade now. One of the authors represents the industry and is also a member of several apex committees in engineering education in India. And the other author represents the academia.

2. ADDIE and the stage gate process

Programs and courses are usually designed using different instructional design models. Understanding and the use of instructional design models becomes significant for this paper. Afsaneh Sharif and Sunah Cho [8], compare various instructional design models, deployment of these models by practitioners and the role and development of the practitioners in their work.

2.1. ADDIE model

ADDIE, a generic instructional design model has evolved over the years and has not been propounded by a single author. It is one of the most widely used model both in the industry and academic environments. The model consists of five stages namely Analyze, Design, Develop, Implement and Evaluate.

Figure 1: Stages in ADDIE

Figure 1 shows the stages of ADDIE arranged in sequence. In stage 1 (Analyze) the learning needs are analyzed. The design of the learning experience as part of a program or course is done as part of stage 2 (Design). In stage 3 (Develop), the content, assessment methods, teaching as well as learning methods and all the other resources including digital and physical facilities required are prepared. The program or course or module is delivered as per the design requirements in stage 4 (Implement). In stage 5 (Evaluate), the program or course, the design method, the development process, the delivery mechanism and the attainment of learning needs are checked.

Gülçin Mutlu [9], Johanes Sapri et. al. [10] and Jiwak Raj Bajracharya [11], are all in agreement that ADDIE is one model that is very generic and fundamental to the development and evolution of instructional design. Shahron Williams van Rooij [12], did an elaborate study on how various instructional design models are deployed and there is a desperate need to embed project management as part of instructional design. The study brought out the significance of project management in instructional design process with almost 15% of total time spent by instructional designers being taken by it. Also, studies indicate that instructional design models are under constant improvement and modifications to suit various contexts and applications.

In ADDIE, the stages are linked to each other. The quality of the end output depends on rigor of execution at all the stages, verification of rigor of execution at the end of each stage and guidelines for verification that enable decision making to move to the next stage.

2.2 Stage gate process for new product development

New products meeting customer expectations with all the required quality parameters are developed and launched by companies using the stage gate approach. Robert G. Cooper proposed that new product development is a process. Therefore, process management technologies can be applied. The whole process of new product development can be divided into manageable sub processes. Each of these sub processes is called a stage and the conformance audit points are called the gate in the stage gate process as shown Figure 2.

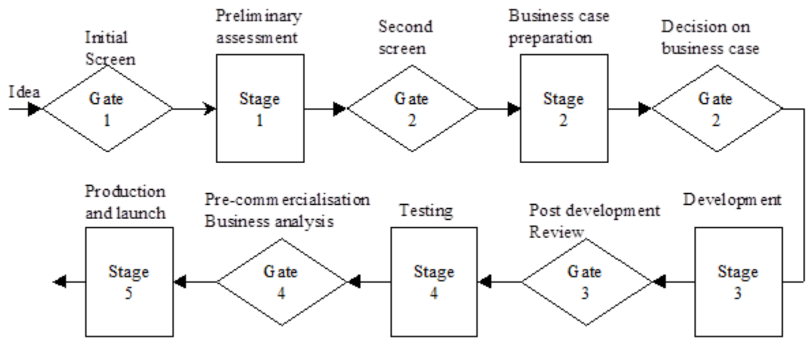

Figure 2: Stage Gate Process in New Product Development

Cooper [13], indicates that even though the process resembles a linear one, in practice there are multiple cycles associated. Further it is said that many projects fail due to poor reviews in the gates due the absence of criteria and score cards. It also indicates the need to go by the scores and not be driven by gut feeling in making decisions at the gates. Anita Friis Sommer and others [14] have reported that implementing scrum for product development in the present-day world does not necessarily mean abandoning stage gate but creating a hybrid that incorporates the features of both for quick product development and launch. Hence even though the stage gate approach is evolving, the fundamental process framework proposed has not changed and has been successfully used by companies to increase development speed, ensure better quality, inculcate greater discipline, and achieve better performance compared to informal development. Edger Scott [15] advocates that apart from the many benefits the stage gate process provides, it ensures that the new product or service offer unique and new benefits to the customer that are superior in value.

This work proposes integration of ADDIE and stage gate for programs and courses in an outcome-based education environment. Rigor of execution of each stage is focused upon using activities. The quality of reviews between stages is ensured using the criteria. Checklists and rubrics are developed and used in the decision-making process.

3. Integration of stage gate process with ADDIE

A team of identified faculty members working in the area of curriculum design were given an orientation on the stage gate methodology practiced in the new product development used by industries. The orientation was followed by brainstorming sessions on stage gate methodology for programs and course design.
ADDIE was introduced with gates in between each stage. Like new product development, the activities, deliverables of each stage, the working teams, and gate keepers were identified, and criteria to help gate keepers make decisions were formulated. After multiple revisions, the stage gate process for programs and courses were presented to statutory committees who approved it for implementation.

3.1. ADDIE with stage gate process for programs

Figure 3 shows the ADDIE model with stages and gates that was designed and developed for programs.

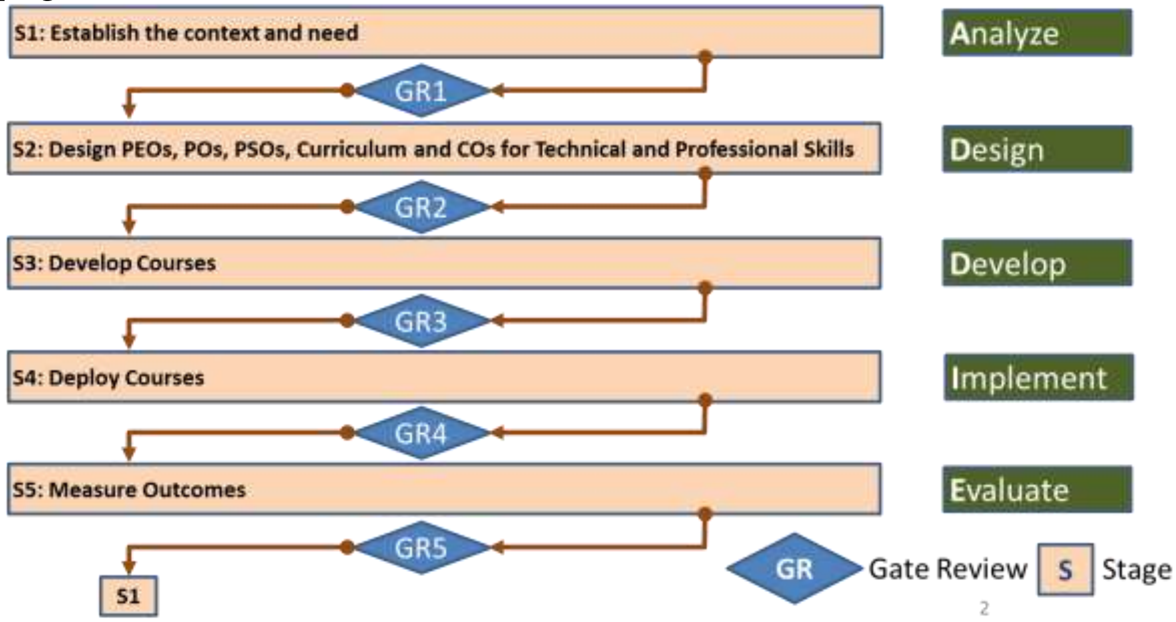

Figure 3: ADDIE with Stages and Gates

As part of the stage gate process, the working teams perform the activities of various stages. Deliverables are achieved at the end of each activity. The gate keepers review the deliverables with the help of the criteria and take decisions (GO/KILL/HOLD/RECYCLE) during the gate reviews.

For example, the first stage is to establish context and need. The main activities of this stage are namely .

a. Survey stakeholders
b. Collate the inputs from various stakeholders

The working team consists of the faculty members responsible for quality improvement in programs, curriculum redesign and some more faculty members to carry out the activities part of this stage. The gate keepers are the senior administrators of the academic institution, the head of the department of the program concerned and curriculum design process specialists from academia and industry.

The deliverables are namely

a. Survey forms (Employer, Alumni, Academicians, Student and Parent)
b. Survey consolidation (domains, skills/competencies)
c. Placement/higher studies/entrepreneurship statistics
d. Program outcome attainment reports

The decision-making criteria are as listed below.

a. Target no. of survey forms
b. Identification of current industry trends and competencies required
c. Target percentage of students getting placed, going for higher studies and doing business
d. Target percentage in PO attainment

The details pertaining to the number of activities, deliverables and the criteria for ADDIE with stage gate process for programs is given in Table 1.

Table 1: Number of activities, deliverables and the criteria of stage gate process in ADDIE

Stage/Gate	Activities	Deliverables	Criteria
Establish context and need	2	4	4
Design PEOs, POs, PSOs, Curriculum, COs	8	7	4
Develop courses	18	14	11
Deploy courses	4	4	1
Measure outcomes	4	4	1

The activities were independent tasks (survey stakeholders), however the deliverables and criteria were categories (survey forms, current industry trends).

3.2. Stage gate process for courses

The third stage of the ADDIE of program with stage gate was further expanded, as the development of courses involved many activities. Figure 4, shows the stage gate process model for development of courses.

For example, the first stage of course development is, develop learning outcome (LO), specific outcome (SO), content and methodology.

The main activities of this stage are namely

a. Formulate course development team
b. Develop enabling outcomes (LO and SO)
c. Develop content and methodology
d. Sign off design document

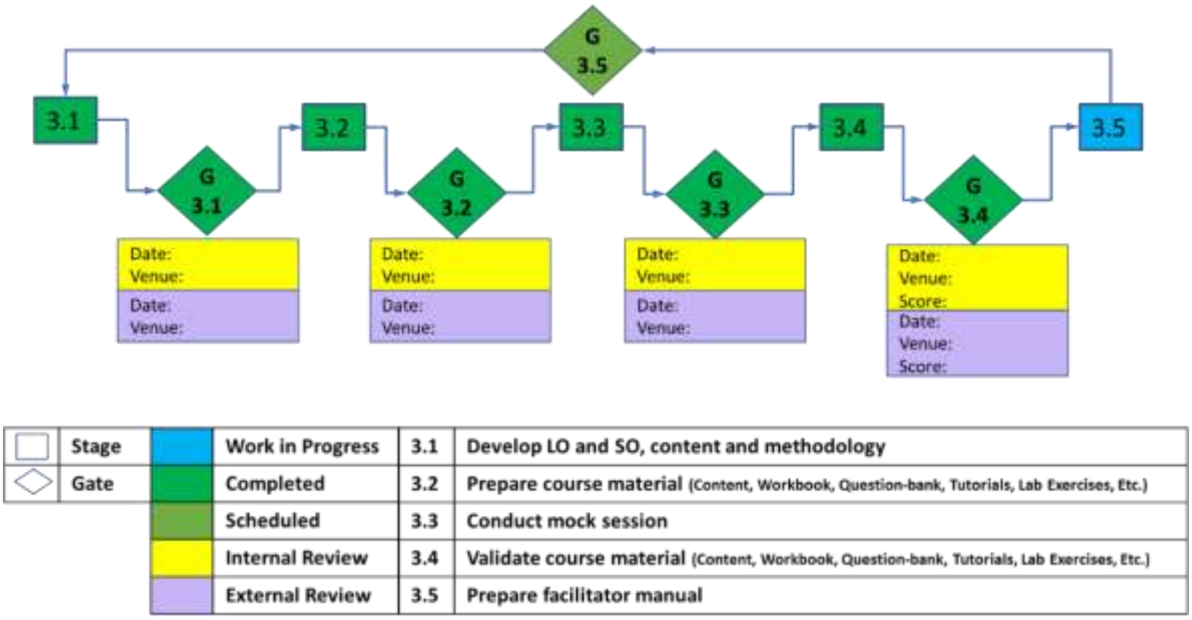

Figure 4: Course Development with Stages and Gates

The working team consists of the Program Coordinator, internal and external subject matter experts, course coordinator and the faculty team formulated for the course development. The gate keepers are the heads of the department of the program concerned, curriculum design process specialists, external subject matter experts from the industry and faculty members responsible for quality improvement.

The deliverables are namely

a. Mind maps for courses
b. Learning outcomes and specific outcomes for course outcomes
c. Design document for courses

The decision-making criteria are namely

a. Team consisting of internal and external subject matter experts in relevant area
b. Design document meeting the criteria specified in the checklist

The details pertaining to the number of activities, deliverables and the criteria for course development with stage gate process is given in Table 2.

Table 2: Course Development Stage Gate Process

Stage/Gate	**Activities**	**Deliverables**	**Criteria**
Develop LO, SO content and methodology	6	3	2
Prepare course material	6	6	5
Conduct mock session	2	2	2
Validate course material	3	1	1
Prepare facilitator manual	1	1	1

Color schemes were used to indicate the process completion and review status as seen in figures 3 and 4. The internal review had expert faculty members from the same or allied departments as reviewers, whereas the external reviews had experts from the industry part of the review process. The new framework was implemented in the Bachelor of Engineering (B.E.) with specialization in Mechanical Engineering program as part of the program redesign. Three full cycles of course development have been completed for a freshmen course "Introduction to Engineering" offered to B.E. Mechanical Engineering program in the institution that has adopted outcome based educational model. The implementation of the stage gate approach in improving the quality of this course has been explained in the following sections.

4. Stage gate process implementation in “Introduction to Engineering” course

The course “Introduction to Engineering” is being offered to first year students of B.E. Mechanical Engineering program since 2015. The redesign of the course using the stage gate process was carried out during 2017-18. The team for the course development was drawn from faculty members of department, subject matter experts from an automotive major (original equipment manufacturer – OEM) in the country. The working team consisted of four faculty members teaching the course and three experts from the industry. The review team consisted of two senior faculty members from the department and one expert from the industry. The working team also inducted faculty members from electrical and electronics engineering department since their expertise was required in some course outcomes. The entire course development spanned over 6 months with several meetings and gate reviews. The comments during gate reviews were systematically captured and incorporated in the course development.

Samples of mind-map, design document, mock session effectiveness rubrics, content and workbook review rubrics which are some of the important deliverables in the course development of Introduction to Engineering, which reflect the course refinement, are discussed in the following sections. The data captured and used in reporting the study are secondary in nature and are taken from publications of the institute available with open access. Also, students participating in giving feedback were given clear indications of purpose of the feedback and were also given the option not to participate.

4.1. Mind map

As part of course development the working team consisting of faculty members and industry experts used the mind mapping activity to arrive at the enabling outcomes. First the team decided on what needs to be addressed to address the course outcome as part of mind mapping. Then this was reviewed by the review team using criteria and then the review comments were incorporated into the mind map before it went as input to the next activity. The mind map for one of the course outcomes of the course Introduction to Engineering on “Explain the career opportunities in engineering in terms of roles and competencies” developed during the course development process is given in Appendix 1.

4.2. Design document

A design document was developed that had details on the entire course design. It indicated the enabling outcomes, content to be covered, Bloom’s taxonomical level of the outcomes, the knowledge type being addressed and the teaching as well as learning strategy to be used to deliver the content, the resources required and the possible assessment questions that can be asked. Appendix 2 shows a portion of the course design document developed by the working team.

4.3. Mock session

Mock sessions were conducted to test the effectiveness of the content developed with a set of students who volunteered. The participants of the session appeared in a test immediately upon completion of the mock session and provided feedback about the session as well. Rubrics indicating the performance requirement of the participants of the mock session was developed and used. If majority of the participants were rated at excellent and good in majority of the criteria, then the content and methodology were cleared in the gate review. The rubrics were unique to each outcome of the course. Mock sessions were conducted for the most significant outcome of the course. Appendix 3 shows the rubrics used for rating the performance of participants in course outcome 4 of the course "Introduction to Engineering".

4.4. Content and workbook evaluation

One of the important activities in the process was the internal and external review of content and workbook while validating course material. As part of the gate review, this was done using a double-blind approach, wherein once it was done by internal reviewers and one more time by the external reviewers who are industry experts. The decision-making criteria were built into a rubric that was used by the gate keepers to make decisions on the course content and workbook. Appendix 4 shows the rubrics used for rating the course content and workbook of the entire course "Introduction to Engineering".

After execution of all the activities and clearing all the gate reviews, the course was deployed. "Introduction to Engineering" has been deployed twice after the introduction of the stage gate process and once before the introduction of the stage gate process. The following section highlights the improvements in the quality of course material, delivery methods, assessments and student performance.

5. Quality improvements through stage gate process implementation in "Introduction to Engineering"

The gate reviews improved several aspects of the course. The industry experts with understanding of instructional design were able to contribute significantly to make the course address contemporary issues relevant to the course. Their contributions during the early stages of the course development and during gate reviews resulted in improvements in course material, delivery methods and level of assessments. Improvements were observed in overall student performance. The following sections indicate some of the improvements experienced.

5.1. Quality improvements in course material

The course material was systematically developed with multiple gate reviews as discussed in the previous sections. Workbook and laboratory worksheets were introduced for the first time based on comments in the gate reviews. Also, the content was refined with removal of good-to-know content. Only the need-to-know content relevant to the course outcomes were retained and all the good-to-know content were pushed to the self-study part of the course. Appendix 5 shows the improved course material after the implementation of the state gate process. It shows a sample content of a presentation that introduces the definition of an engineer. In the version before the implementation of stage gate, the same content was a definition with few sentences, whereas it can be seen here that a question-based discussion is being used with hints given using images as part of the content. It also shows a sample workbook corresponding to the content. Before the introduction of stage gate process there was no workbook being used for the course. Appendix 5 also shows the worksheet developed for tutorial and laboratory exercises. Before the stage gate process was implemented there were no hands-on exercises involving products for students. However, after stage gate process was implemented in the course, hands-on exercises along with tutorials were developed for the course.

5.2. Quality improvements in delivery methods

The course design necessitated the integration of tutorials and laboratory exercises in some course outcomes. Hence these were renamed RIALABs (tutoRIAl LABoratory). This new method was specifically designed for the course. It consisted of exercises where some parts were carried out as tutorials. The findings and results of tutorials were verified with the help of exercises in the laboratory. For example, in the tutorials students identified different materials that could be used for making parts of the products. Later in the laboratory the students saw the parts and verified their choice of materials for the parts of the products. After experiencing the improvements in student performance with the introduction of the stage gate process, the working team of the course decided to adapt a similar approach in the laboratory sessions of the course. For all the RIALAB exercises in the course the working team introduced checkpoints with a holistic rubric. Appendix 6 shows the RIALAB worksheet for an exercise. The holistic rubrics as part of the checkpoints 1 and 2 are also seen. Multiple opportunities to refine and improve reflected positively in student learning. Improvements were observed in the learning exhibited by the students and the same is reflected in the course outcome attainments (reported in section 5.4).

5.3. Quality improvements in assessments

Along with the improvements in course material and delivery methods, the assessments and methods of assessments also improved. The question being asked in the tests directly correlated with the enabling or course outcomes. More apply level questions were introduced into the assessments after the stage gate process was implemented. Too many questions at the remember and understand levels were avoided. For. example, a question like “Explain any two graduate attributes” was replaced with “Propose a suitable intervention plan for improving the skill sets of Indian engineers to improve their employability”. With practice gained in the interactive lectures, tutorial and laboratory sessions in the course, students were at ease in applying the concepts. For. example, a question like “Write minimum six parts, their functions, materials, and manufacturing processes of any one product used in your day-to-day life” as part of a test after students did RIALABs on different products was easily answered by many students with many options of the products selected from the ones that they have not already come across in the RIALABs.

5.4. Improvements in student performance

The overall course performance and the course outcome attainment of the batches of students that took the course before the implementation of stage gate process (BI-SGP) and after the implementation of stage gate process (AI-SGP) were compared to understand the improvements in student performance. The freshmen batches chosen were from consecutive academic years with 111 students (BI-SGP) and 147 students (AI-SGP) registered in the course. There were three written tests of 90 minutes duration and one exam of 180 minutes duration along with 8 exercises performed in the laboratory for the course, which were considered for comparing the marks, grades and outcome attainments. Details regarding some more aspects of assessment have been discussed in section 5.3. Lab exercises were repeated across both the batches, but had different methodologies as discussed earlier in section 5.2.

The Course Outcomes (COs) for the course are listed below.
1. Explain the career opportunities in engineering in terms of roles and competencies.
2. Explain how a student can acquire the competencies.
3. Explain how to remain, relevant and versatile in a dynamic and complex environment.
4. Observe every product and processes with an engineering perspective and inquisitiveness.
5. Choose to take ownership for learning and development leveraging the resources and infrastructure.
6. Follow environment friendly and safe practices in different contexts of daily life and work.

The mean grade point average for the course improved from 7.12 to 8.14 between the two batches. The outcome attainments in the outcomes also improved significantly in majority of the course outcomes. A null hypothesis testing using two sets of data pertaining to the marks scored by the two batches of students was carried out with two tailed, unpaired, T-test with significance level of 0.05. The absolute value of the calculated value exceeded the critical value as shown in table 3, so the mean score of the students were significantly different.

Table 3: T-test results on the marks of two batches of students

	BI - SGP	**AI - SGP**
Mean	72.8	77.7
Variance	87.8	167.0
Stand. Dev.	9.4	12.9
n	111	147
t	-3.5892	
d.o.f	256	
critical value	1.968	

Figure 5 shows the outcome attainment reported for various outcomes of the course on the Likert scale of 3. In COs 1, 2, 3 and 4 there was improvement in the attainment of outcomes. In CO5, there was a drop observed since the students avoided answering questions from the CO as it involved lot of theory. CO6 on safety was also assessed for the first time. Significant improvement was observed in CO4. This CO involved the RIALABs and had the checkpoints (stage gate process) in the exercises.

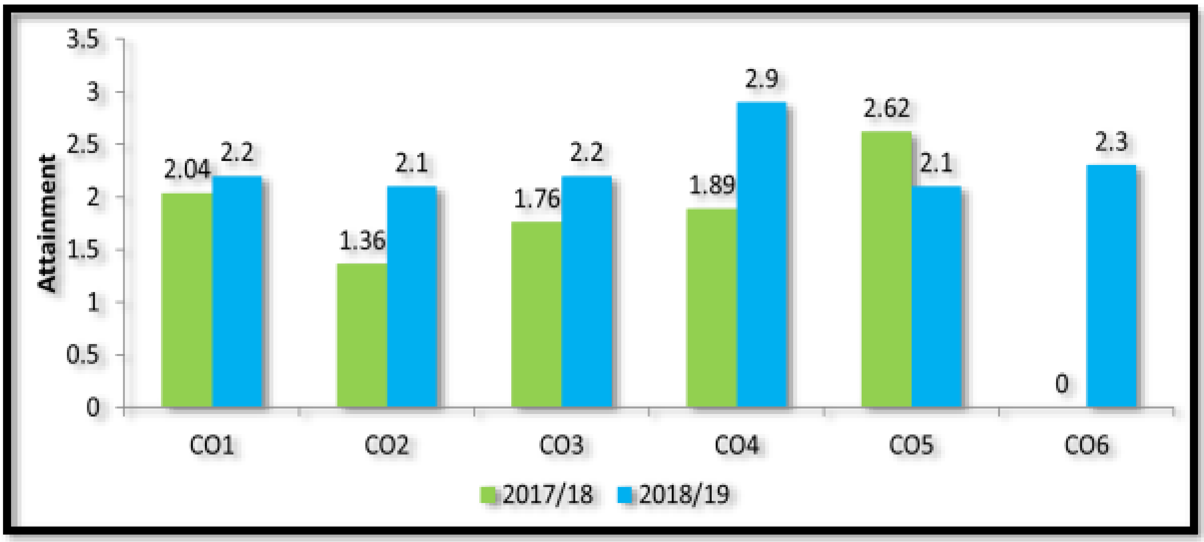

Figure 5: Outcome attainment comparisons between batches of students without and with implementation of stage gate

A structured feedback was collected using a survey with students registered in the course. The feedback had 15 criteria covering various aspects of the course and instructor. Student volunteers were asked to write testimonials at the end of the semester as well. The feedback and the testimonials indicated that students were very happy about the course, its delivery and the assessments. Students felt that there were significant learning experiences with respect to the course as well as learning how to learn. While introduction of stage gate process had improved several aspects of the quality of the course and hence the attainment of outcomes, two major challenges were faced. The following sections describe the two major challenges and how they were overcome.

6. Challenges in implementation of stage gate in programs and courses

The faculty members involved in program and course design were totally new to stage gate process. Training sessions on stage gate process were required before the process could be used in courses. Also, the rigor in the activities and gate reviews were missed by faculty members in the initial few occasions. However, the method of having internal gate reviews with faculty members and external gate review with industry experts helped in setting off the rigor. On several occasions the deliverables were cleared by the internal gate reviews but were sent back for recycling in the external gate reviews. In the subsequent reviews there were minimal differences between the two. The industry experts' time were very difficult to obtain. The faculty team had to make several visits to the industry or invite the industry experts to the departments for reviews. This was highly resource intensive. In the absence of industry experts, the improvements made would not have been possible, especially in the Indian context.

7. Conclusion

Indian engineering education system is undergoing a rapid transition with many efforts at the macro level to improve quality. But there are gaps when the implementation happens at the last mile due to lack of innovation. With involvement of the industries in every stage of the program and course design, development, deployment and evaluation, ADDIE with stage gate process may prove to be one such innovative approach resulting in the improvement of quality of programs and courses in engineering education. Rigorous implementation of stage gate process with active involvement of industry persons in the design, development, deployment and evaluation of a freshmen's course titled "Introduction to Engineering" has shown the extent of course refinement and improvement possibilities in learning outcomes of students.

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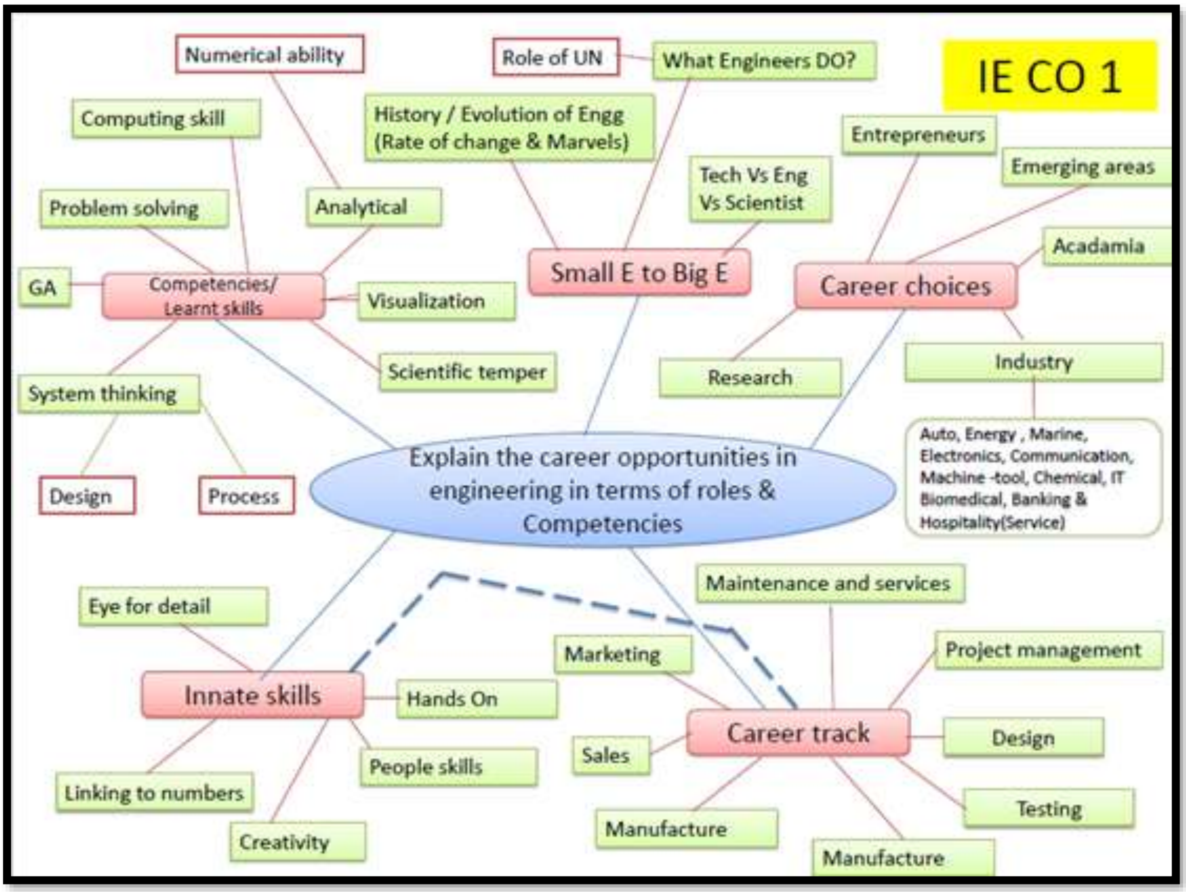
Appendix 1: Mind map of course outcome 1 of "Introduction to Engineering"



Appendix 2: Portion of the design document of course outcome 1 of "Introduction to Engineering"

Course Outcomes (CO) (What the student will be able to do on completion of the course)		**Learning Outcome (LO) (What the student should be able to do if he/she must do the relevant CO)**		**Specific Outcome (SO) (What the student should be able to do if he/she must do the relevant LO)**		**Classification**		**Content (The content that needs to be covered if the student must do the relevant SO)**
						Type of knowledge	**Bloom's cognitive level**	
By the end of the course, students will:		By the end of the course, students will:		By the end of the course, students will:				
1	Explain the career opportunities in engineering in terms of roles & competencies	1.1	Explain the concept of small e to big E	1.1.1	Differentiate between technicians, and engineers.	Conceptual	Understand	Description of technicians, engineers and scientists. Dignity of labour. Differences between technicians and engineers

Methodology					**Assessment Questions**
How the content will be delivered			**Tools/Logistics**	**Time**	
File No.	**(What faculty will do)**	**(What student will do)**		*(in Minutes)*	
Lecture CO1-1	F1. Conduct QBD for the definition of an Engineer. F2. Show videos and ask students to list the activities being performed by a technician, engineer, scientist. F3. Conduct QBD on activities performed by engineers, technicians, and scientists to indicate the significance of dignity of labour. F4. Explain the differences between engineer and technician. F5. Ask students to list a few examples for each using the workbook.	S1. Give answers to QBD and hence define an engineer. S2. List all the activities for engineer, technician, and scientist in the workbook. S3. Give answers to QBD and hence explain the dignity of labour. S4. Differentiate engineers from scientists and technicians. S5. Students list a few roles such as QC engineer, plumber, nuclear scientist etc.	PPT, Projector, Video on "Engineers, Technicians, Scientist in action". Workbook.	30	1. Differentiate an engineer from a technician 2. Is a two-wheeler mechanic an engineer? Justify 3. Explain dignity of labour

Appendix 3: Rubrics for rating performance of participants in mock session for course outcome 4 of “Introduction to Engineering”

CO 4: Observe the given product with an engineering perspective

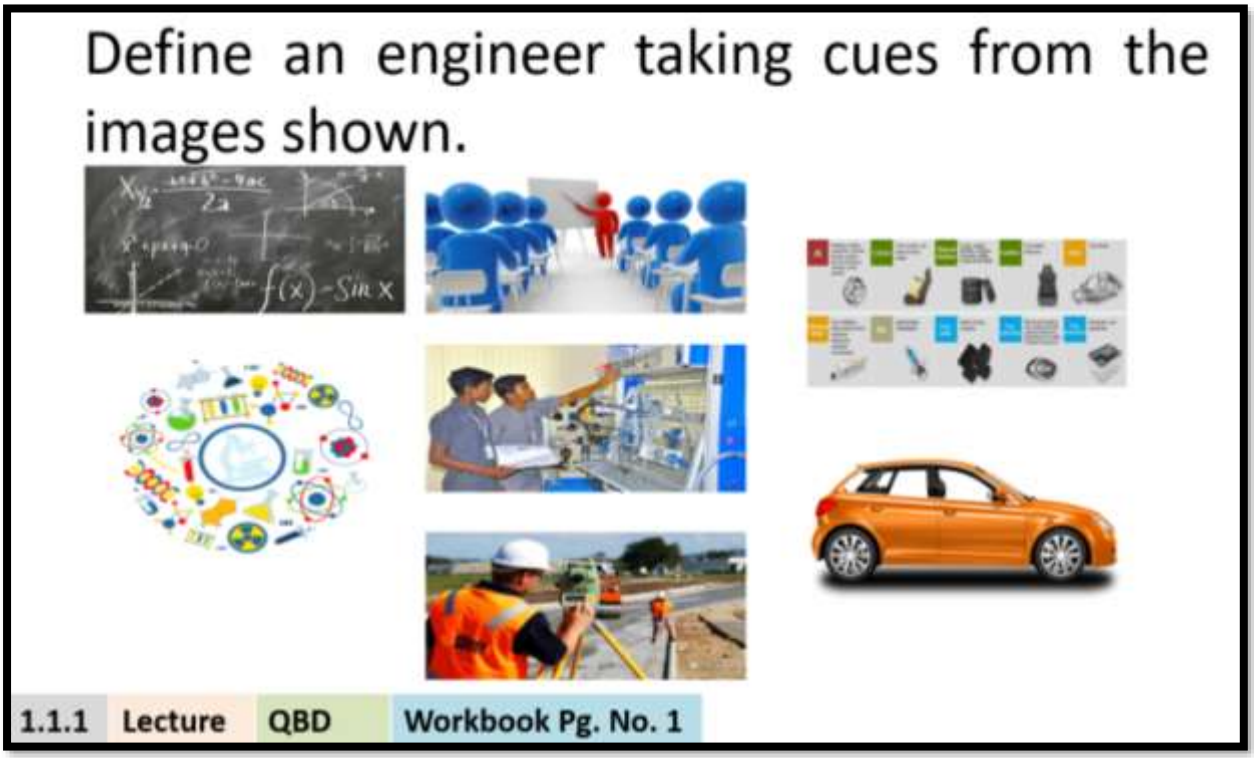
	Excellent	Good	Satisfactory	Needs Improvement
Primary Function of Product (20%)	Writes the primary function of the product exactly with a noun and a verb	Writes the primary function of the product	Writes a primary function which is not associated with product	Writes no function of the product
Secondary Function(s) of Product (20%)	Writes the secondary function(s) of the product exactly with a noun and a verb	Writes the secondary function(s) of the product	Writes secondary function(s) which is/are not associated with product	Writes no secondary function(s) of the product
Working (10%)	Explains the working of the product precisely demonstrating full understanding of the product	Explains the working of the product	Explains the working of the product vaguely	Explains the working of the product wrongly
Parts (10%)	Lists all the important parts	Lists some important parts	Lists a few important parts	Lists no parts
Function of Parts (10%)	Lists the functions of all the parts using a noun and a verb	Lists the functions of some parts using a noun and a verb	Lists the functions of parts	Lists no functions of parts
Materials of Parts (10%)	List the material used in all the important parts	List the material used in some of the important parts	List the material used in a few parts	Lists no material
Manufacturing Processes of Parts (10%)	Indicates all the manufacturing processes used in making of the parts	Indicates some manufacturing processes used in making of the parts	Indicates a few manufacturing processes used in making of the parts	Indicates no manufacturing processes used in making of the parts
Scientific Principles (10%)	Explains at least one scientific principle associated with the product	Explains at least one scientific principle but it is not explained well	Explains at least one scientific principle but it seems irrelevant	Explains no scientific principle associated with the product

Appendix 4: Rubrics with rating of entire course content and workbook by industry expert and faculty peer

S.No.	Criteria	Level 1 (Score 0)	Level 2 (Score 1)	Level 3 (Score 2)	Level 4 (Score 3)
Content evaluation					
1	Usage of suitable presentation media such as MS Power Point, Key Note etc.	Not Used	Used		
			✓		
2	Alignment to outcomes	Not Aligned	Aligns some what	Aligns mostly	Aligns completely
				✓	
3	Alignment to Bloom's level and the type of knowledge	Not Aligned	Aligns some what	Aligns mostly	Aligns completely
				✓	
4	Correlation to content in DD	Does not correlate	Correlates		
			✓		
5	Correlation to methodology in DD	Does not correlate	Correlates		
			✓		
6	Presence of only need to know	Completely good to know	Mostly good to know	Mostly need to know	Completely need to know
					✓
7	Usage of strategies such as QBD, known to unknown and other similar	Not used	Used occasionally	Used mostly	Used extensively
				✓	
8	Appropriate structuring to have ice-breaker, recap, main content, summary, formative assessments	No components	Few components	Majority of components	All the components
			✓		
9	Formatting of the content for the size of the class room	Not formatted	Formatted		
			✓		
10	Instructions to use the workbook	Not available	Available		
			✓		
Workbook evaluation					
11	Usage of suitable documentation media such as MS word, Key Note etc.	Not Used	Used		
			✓		
12	Compilation in the same order as that of the content	Not in order	In same order		
			✓		
13	Adequate spacing for the questions/activities	Not spaced	Appropriately Spaced		
			✓		

S.No.	Criteria	Level 1 (Score 0)	Level 2 (Score 1)	Level 3 (Score 2)	Level 4 (Score 3)
Content evaluation					
1	Usage of suitable presentation media such as MS Power Point, Key Note etc.	Not Used	Used ✓		
2	Alignment to outcomes	Not Aligned	Aligns some what	Aligns mostly	Aligns completely ✓
3	Alignment to Bloom's level and the type of knowledge	Not Aligned	Aligns some what	Aligns mostly	Aligns completely ✓
4	Correlation to content in DD	Does not correlate	Correlates ✓		
5	Correlation to methodology in DD	Does not correlate	Correlates ✓		
6	Presence of only need to know	Completely good to know	Mostly good to know	Mostly need to know ✓	Completely need to know
7	Usage of strategies such as QBD, known to unknown and other similar	Not used	Used occasionally	Used mostly ✓	Used extensively
8	Appropriate structuring to have ice-breaker, recap, main content, summary, formative assessments	No components	Few components	Majority of components	All the components ✓
9	Formatting of the content for the size of the class room	Not formatted	Formatted ✓		
10	Instructions to use the workbook	Not available	Available ✓		
Workbook evaluation					
11	Usage of suitable documentation media such as MS word, Key Note etc.	Not Used	Used ✓		
12	Compilation in the same order as that of the content	Not in order	In same order ✓		
13	Adequate spacing for the questions/activities	Not spaced	Appropriately Spaced ✓		

Appendix 5: Sample content, workbook and lab worksheet of the course “Introduction to Engineering”



LO 1.1 Explain the concept of small e to BIG E

Define an engineer in the taking cues from the images shown.

Brief notes on definition of an Engineer according to ABET.

Watch the videos (1.1 and 1.2). Write what an engineer does and what a technician does.

Learning Outcome:

4.3 Explain how products are made and its various stages.

At the end of lecture you will be able to

Answer the following questions:

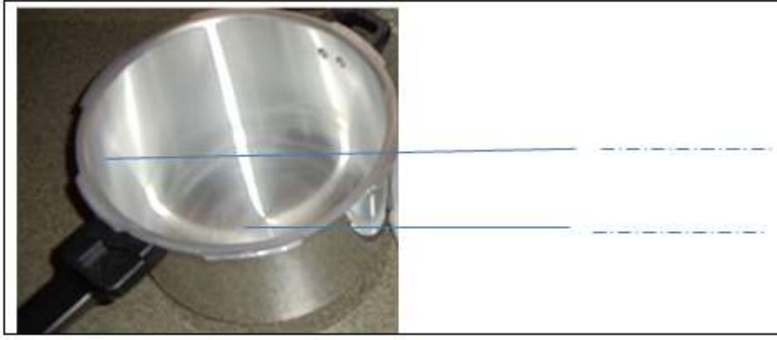
From AV:

4.3.a Which product is made?

4.3.b What are the processes used in this product?

4.3.c Prepare a flow diagram for "how the products are made?"

4.3.d Identify the parts marked. Also write the process involved in making those parts?



Part name	Process involved

4.3.e Measure the quantity of ingredients used for any 2 different items.

- No of whistles.
- Time taken.

Appendix 6: RIALAB worksheet with checkpoints

CO4: Observe every product and processes with an engineering perspective and inquisitiveness

RIALAB 1: Primary and secondary functions of products and their equivalents

Aim(s): To

1. Write primary and secondary functions of products

2. Identify equivalent products, which perform same functions

3. Compare equivalent products performing same functions

Students pick lots to choose a product

1. Define product

2. Explain the purpose of the chosen product

S. No.	Product Name	Purpose of the product
		Original:
		Revision 1:
		Revision 2:

Check Point 1: The purpose relates to the need and is stated with a verb.	

3. Write the primary function of the chosen product

S. No.	Product Name	Primary Function
		Original:
		Revision 1:
		Revision 2:

Check Point 2: The primary function is the main job of the product.	