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PO Assessment and Attainment through POGILbased classes

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Abstract: This paper describes the development of POGIL based instructional design classes for complex engineering problems described in the Program Outcomes (PO) of National Board of Accreditation (NBA), India accreditation criteria. Embedded system Design course in Electronics and Communication Engineering course (ECE) is considered for experimentation. Subsequently it aims at providing students and interested fresh faculty an opportunity to design and build the project on their own. The aim of the project is to design a round robin based embedded system where the tasks are of their choice. To structure and complete their design part, both students and faculty were posed with a large number of questions. They were asked to refer literature and data sheets for their work. Once the design part was reviewed to avoid critical errors, students built their project and compared solutions to theoretical predictions. Feedback was collected and analysed to determine the effectiveness of POGIL in PO attainment. The reflections given by both faculty and students were positive, in particular students found that solving complex engineering problems are quite difficult and challenging compared to other prescribed book end exercises but POGIL helped them to be more constructive to build their knowledge

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1. Development of Graduate Attributes-Background

The focus of the Higher Education system has been shifted to align with the goals of employers, government and education in recent years. The higher education sector describes the graduate attributes as the competency required to achieve this. Hence the assessment of a University is done based on the attainment of these graduate attributes. This shift in education has resulted in universities being placed under increasing pressure to produce employable graduates. In spite of this global change, Indian Higher Education system is facing fundamental problems in providing quality education due to multiple factors including shortage of competent faculty and the way the high school science education is imparted. Multiple pedagogy are followed to provide a meaningful learning, however attainment of graduate attribute is tightly tied knot as all fall in higher complexity learning outcomes.

Wendy Green, Sarah Hammer & Cassandra Star (2009) have an opinion that the demand for work-ready graduates by the employers around the globe has changed the role of universities to do more for their students than simply transmit disciplinary content. This growing emphasis on quality assurance made the higher education sector to do an active quality research. Graduate attributes are outcome of their research and they are nothing but the

„skills, knowledge and abilities of university graduates" that extend beyond traditional disciplinary outcomes (Bowden, Hart, King, Trigwell & Watts (2000). They are of wide range and more panoptic than "employability," helping to develop academic, social responsibility and career competencies. Some common graduate attributes which gained favour in universities, are critical thinking skills, such as intellectual curiosity, structured thinking, problem-solving and insightful judgment; effective communication; leadership and teamwork skills; research and inquiry skills; personal attributes such as self-awareness, self-esteem, adaptability and creativity; and personal values such as ethical, moral and social responsibility, integrity, and cultural diversity consciousness.

International accords are used as standards for recognition of graduates around the globe from accredited programs. The Washington Accord (WA), Sydney Accord (SA) and Dublin Accord (DA) provides for mutual recognition of programs accredited for the engineering track, engineering technologist and engineering technicians respectively. These accords are based on the principle of significant equivalence rather than exact correspondence of content and outcomes. India has become the member of WA in 2013 and hence NBA India follows the 12 graduate attributes given by WA and they are called Program Outcomes (POs). Quite a lot number of steps have been taken by NBA to improve the education, however it is the responsibility of the educators to internalize it in addition to have it in the paper..

Nghiem, Goldfinch. Bell. (2010) have discussed the issues incorporating multiple skills in addition to technical competency in Australia where the outcome based education started much earlier compared to India. In addition, it is a big challenge in India due to well-grounded poor quality of education and many engineering educators find it difficult to incorporate them into their curriculum. Extensive engineering education literature talks about PO since it first appeared in NBA, but most of the discussion has focused only on assessment and attainment computation rather than about what must be done to achieve those POs (Darrall (2008),Hughes & Barrie (2010), Bhimasen Soragaon & Mahesh (2015), Priya Sawant (2016)). It is because the assumption is that determining whether or not students have specific skills is much harder than equipping them with those skills. However the ground truth is the flip side. This can be seen in the mapping of course outcomes (COs) and POs done by several Self- Assessment Records available. The design of filters has been linked to PO-3 which talks about design and development of solutions for complex engineering problems. A word to word linking between CO and PO has been done without understanding the real underpinning behind the definitions of PO. Due to the lack of conceptual clarity POs are only at the policy level (Barrie, S. 2005), some educators even think that POs require a unique set of outcomes which are different from CO of a module. This is not the case, as POs are attainable together with COs using the descriptors given within POs. The ability of the faculty to deliver POs still fall short on two counts in most of the universities and Institutions, primarily faculty should come out of doing word matching between COs and POs, secondly need to design teaching learning strategies appropriate for delivering the POs including providing appropriate assessment mechanism

This paper explains how an innovative pedagogy "POGIL" can be used as an effective tool for the delivery of technical POs towards attainment and in particular for assessment. Section I discusses the background information about Graduate attributes which are primarily POs described in NBA. Section II discusses the ways to personify POs into curriculum. Section III discusses case study on how POGIL can be used as appropriate delivery as well as assessment mechanism for personifying technical POs for communication engineering course. Section IV discusses the results and section V concludes the paper.

2. Personification of PO through POGIL

Hughes & Barrie (2010) emphasize that each descriptor given in the PO statements should be measured by the educators not POs itself. Subsequently, personifying POs into an engineering curriculum requires educators to develop COs with specific and measurable descriptors. Reviewing and analysing the COs of a curriculum, is therefore a good starting point in determining to which extent, the various POs have been personified into an Engineering curriculum. COs and teaching and learning activities are at the centre of higher education. They complement each other in the sense that COs influence the selection and organization of teaching and learning activities (Barry (2005). Simple, curriculum mapping for the attainment of PO has the potential to promote a superficial approach to

developing POs unless appropriate instructional delivery strategies are used and substantiation of implementation is pursued (Sumison & Goodfellow, 2004, Hughes & Barrie (2010), Biggs (2011)). Rachel Spronken et all (2014)) have given guidelines to self-assess an Institution that if meaningful POs are personified into the curriculum and it is followed.

- Planning for POs –High level strategic plan must be done to define POs by the Institutional teaching and learning centre
- Systems to personify POs – There should be an institutional processes describing roles and responsibilities of each committees, of faculty for initiatives including POs planning and personifying
- Delivery of POs – Flexibility in teaching and assessment should be encouraged to explicitly teach towards achievement of POs
- Assessment of POs - Development of POs through assessment should be encouraged
- Evaluation of attainment of POs – Monitoring of attainment of POs across the institution must be ensured by the process committee
- Professional development support for POs - Academic faculty development support should be provided to assist academics to engage with a PO agenda

In Indian context it is assumed that planning step is not required as POs have been defined by NBA and hence it is not discussed here. POs are expected to be incorporated into the COs as POs are measured partially at the end of the module and completely at the end of the program with the help of COs. It is important for educators to use indicators or descriptors of competencies embedded within the PO statements rather than plain blooms verbs (Lawrence Meda & Arthur James Swart, 2017) for personification and this will make POs identification process that need to be found across any given curriculum in higher education.

2. POGIL an appropriate delivery mechanism for personifying technical POs

The POs and the pedagogic design must be integrated so as to ensure that students are carefully guided to construct the knowledge on their own. POGIL has been used as a knowledge construction mechanism by the educational researchers (David M. Hanson (2003), Douglas & Chu- Chuan Chiu (2012)) in various fields including marketing and it has brought in positive results in science and engineering teaching. It revolves around four stages i.e. orientation, exploration, concept formation and application. Closely related pedagogy which inculcates critical thinking skills is Problem based learning and Project based learning. However problem based learning is usually is multi-disciplinary in nature and involves the integration of Journal of Engineering Education Transformations, Volume , No, Month 2015, ISSN 2349-2473, eISSN 2394-1707concepts rather than understanding the concepts itself. Project based learning needs the faculty as well as the student to be well familiar with hands-on tools. Hence for a learning teacher POGIL will be the effective teaching methodology.

Due to its very nature of making students to link the concepts learnt earlier with the current learning it is possible for the students to even link engineering solution for a complex problem with the societal problems. However the only help needed by the

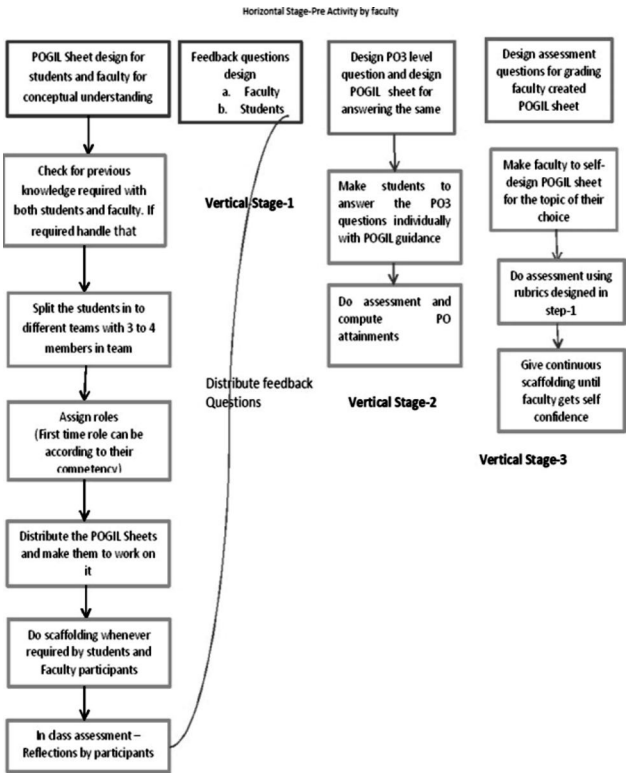

Fig.1 : Research Flow Diagram

students from the faculty are to present large number of questions leading to the solution. Hence the role of the faculty is crucial here and needs an extensive knowledge not just to present the facts but to impart a thinking capability. Douglas & Chu- Chuan Chiu(2012) and the Masoodhu Banu &Rajeswari (2017) have proved that POGIL can be successfully used for knowledge construction.

The research flow adopted is presented in figure 1. The horizontal step where the blocks are shown in blue color is the pre design activity by the faculty. Stage 1 is in class POGIL activity conducted both for novice faculty and students. Stage -2 is PO assessment for student and POGIL sheet design activity assessment for faculty.

Based on the prior work on POGIL in other fields POGIL activity sheet has been developed for application level in blooms taxonomy for communication engineering course. The same has been discussed here as attainment of CO is the first step for PO attainment. The POGIL sheet development followed four level approach i.e. orientation, exploration, concept formation and application. The orientation stage prepares the students for learning by introducing the learning objective. In the second stage students use the models or activities created by the instructor for analysis and investigation of the data. In the third stage, they invent the concepts. This process is enabled by supplying questions that compel students to think critically and analytically as they engage in the exploration. These questions, which are called guided- inquiry, critical-thinking, or key questions, guide the learner both in the exploration and concept invention stages. Here the learners learn in groups with different roles like manager, recorder, presenter and reflector. As they have specific accountability, their involvement is more. The steps are illustrated with an example given below

A. Activity-1: Pogil activity sheet for understanding the Modulation equation

Students who do learning by memorisation find it difficult even for a word change in the assessment question from the one taught in the class. POGIL questions given in Table. 1 will make the students to answer in whatever form the question is posted to them. Also the other thing noted here is there are times everyone was not correct. For example for the question number 7 all students have answered

. Here the instrcutor role has to explain why has not been considered as a variable quantity, and this question is explicitly needed as it is further used in the concept of modulation index. These kind of discussions by the instructor for the student‟s question how and why in POGIL activity clears any misconception and leads to problem solving skills at the latter stage. In this way students also learn to link new knowledge with existing knowledge.

Table 1. Inquiry Questions for Modulation equation

S No	Inquiry Questions	Expected Ansewrs
1	Write the equation of sinusiod	or Eqn for a sinusoid
2	Write one more sinusoid equation make it and call message signals	, The amplitude is and
3	Idnetify the three variables in the above eqation	Amplitude, frequency and phase angles
4	Change the amplitude of the carrier in the previous equation by adding message signal	The amplitude in equation is changed by A_m+A_c
5	Rearrange the equation by taking outside	( )
6	Identify the factor which changes the term	
7	Identify the variables in the above answer?	and

B POGIL for PO Attainment

The first five POs deal with complex engineering problems. However each POs deal with the complex engineering problem in a different aspect i.e. following is the characteristics defined by [7]. The first five POs defined in NBA guidelines have the common descriptor called complex engineering problems i.e. technical POs. However each POs describes the complex engineering problem in a different aspect and. following are the characteristics defined by Sahasrabudhe (2015)

- It should not be end of chapters exercise problems as the learning phase is predefined here
- The problems should leave at least a few choices for the student to make.
- Problems may require use of fundamental knowledge which may bring in some mathematical tools

In a nutshell the question should mirror what is required in a workplace. Expertise is required to frame such complex engineering problems with more than one descriptor which leads to solutions to societal problems as well. Complex problems should be structured in a different way in order to make it suitable for teaching open ended problem; however it should focus on the field of study and not be diverged. The learner should understand the context of an open ended problem in the first phase as mostly it involves interdisciplinary problems. The second phase involves out of the box thinking to collect some practical information required and finally to structure that to bring out a solution. Though POs are personified in COs it is difficult for students to write an exam within the stipulated time and difficult for the faculty to assess all the descriptors listed in POs in a written exam. Hence in this case study the suitability of POGIL in PO attainment was experimented with final year students in their project phase.

C. POGIL Activity sheet for Complex Engineering Problem

It is a common practice to look for the project centre in most of the private engineering colleges as for as embedded design project is concerned. It is mainly due to the wrong notion of the fact that ECE does not require programming languages. Hence the following question has been framed as a complex problem for the students who were working on embedded system design project during their project induction phase.

- Design a scheduling algorithm for a system with 4 periodic tasks based on sensor inputs. The sensor can be anything from temperature to pressure sensor. Analyze your design for various performance factor of a scheduler

Customarily in text books based problems, the period of the tasks will be given and hence using formulas students will be able to calculate the performance factors. In the problem given above no clue about the period is given, hence without guidance most of the students were not able to solve this problem. Hence it leads to attainment less than 50%. However the guidance cannot be like the class room guidance while explaining the concepts. Hence a set of inquiry questions in every stage of their design process will make them to understand the real time experience and makes them work ready engineers.

The inquiry question and the respective stages are in given in table 2. The design question does not specify the input output and it is the student choice and hence it becomes an open ended question which is the precise requirement of an engineering education. The selection of microcontroller and the operating system also left to the student‟s choice. Choice can be at random but the next work at their hand is finding out the period of the task. It depends on the Analog to Digital converter sampling rate and their conversion time etc. Next comes the conversion method either it can be polling or interrupt. Students will get some idea about their design here to proceed further, without that a random period will make their design never work. If it works at the first instant they never learn the real concepts to be applied in an industrial design. The assessment can also make use of the same table and it can be with respect to how many inquiry questions they have answered correctly and their final design.

Table 2. Inquiry questions and their respective stages

SNo	Inquiry Questions	Inquiry Stage
1	Decide your input and output first.	Context question. This invokes the student to think about what kind of a realistic task to bring in here so that it is periodic
2	How would you determine the period of the task here. The sensor by itself can convert its data to digital ?. If not how it can be converted?. Whata are the specifications of the converter?	Pose infinte number of questions to collect the practical data required
3	How do you calculate the execution time ?. Can you get this data from the converter you have?	Out of the box thinking question. If period and the execution time is not same how to find the execution time? Is there any data available within the data sheet?
4	What is the conversion method you can follow as it is given as periodic tasks (a simple schduling algorithm may be round robin)	Structuring Part
5	How would you choose the OS for your application?	Structuring Part
6	Do you need to consider about inter process communication in your design?. Justify your anser (Can use state diagram for this purpose)	Structuring Part
7	Do you need to consider any priority in your design ? Justify	Structuring Part

4. Feedback and Findings

In order to have a longitudinal study two groups were selected in this case study i.e. Final year ECE project phase students of 4 teams (5 students per team) and appreciative fresh faculty (5 teachers) with self interest for leaning. Both were given a task to complete their project in embedded field. The POGIL excercie was given to them before they proceeded to their project. The group making was not a problem with students as they were already in a group with a purpose, however the faculty wanted to do individually as their main purpose is to understand graduate attributes. A set of questionaries were framed in order to have the formal feedback from the students and faculty about the POGIL classes. There were two types of questions framed objective type and descriptive type. Objective questions were framed in order to guide the students to answer descriptive questions. The questions are given in table 3 & 4. Additional questions were posted to faculty separately and it is given in table 5.

Table 3. Descriptive feedback questions-Students

S. No	Feedback Questions
1	What do you think about the Inquiry questions for self-understanding
2	Do you like to have more questions? If yes or no why?
3	Do you like to have POGIL classes in future? If no state the reason
4	What is the difficulty in linking interdisciplinary concepts required to carry out the project
5	Does POGIL classes reduce your time to review your project implementation for your final viva voce?
6	What did you like most about the Inquiry questions?
7	What do you think that shouldbe improved in Inquiry questions
8	Do you like to work in group ?. If no what is the difficulty

It was really a surprise to see that everyone had answered for both the descriptive type and the objective questions. Also they really had taken some effort in answering too and this is opposed to the feddback got in our earlier work where both interested and not interested students were participated. The analysis of feedback data showed that the 80% of the students liked the POGIL preparatory classes and were able to answer the POGIL activity questions correctly though the effort taken is more. The remaining 20% also liked it however due to their poor basic knowledge they found it very difficult to answer even with books, pointers and explanation by the faculty.

Table 4. Objective feedback questions and survey results

S.No	Objective Feedback Questions	Agree %	Undecided not answered %	Disagree %
1	Inquiry questions have helped me to get the required things to implement my project myself	80	20	0%
2	Inquiry questions approach has forced me to think out of the box than the lecture alone would have	75	25	0%
3	Inquiry questions approach has helped me feel more confident about tackling unfamiliar practical problems	50	30	20
4	The POGIL classes has been effective in improving my problem-solving skills	80	10	10
5	Inquiry questions approach has helped me improve my communication skills	80	20	0
6	Inquiry questions approach has helped me improve my teamwork skills	80	20	0

Table 5. Descriptive Feedback Questions-Faculty

S. No	Feedback Questions
1	What is the difficulty you faced while preparing POGIL activity sheet for your course?
2	Could you identify why you faced difficulty in preparing POGIL Sheet?
3	After creating your POGIL activity sheet, did you experiment it with your colleagues who is not the expert in the course?. What was their reflection
4	How did you feel when students discussed themselves for your structured questions?
5	Could you assess your students immediately with your POGIL setup?

The performance indicator for any pedagogy is student‟s engagement and the outcome attainment percentage. Though student‟s engagement can be mesured by any faculty in class, feedback results of

the question number 2 & 8 in table 3 reflected this. PO outcome attainment was measured before and after their POGIL classes/Training and is shown in below as bar chart in figure 2 & 3. Clear evidence for their fondness towards POGIL classes reflected from their performance after their POGIL classes. In case of faculty it was measured for their efficacy in teaching.

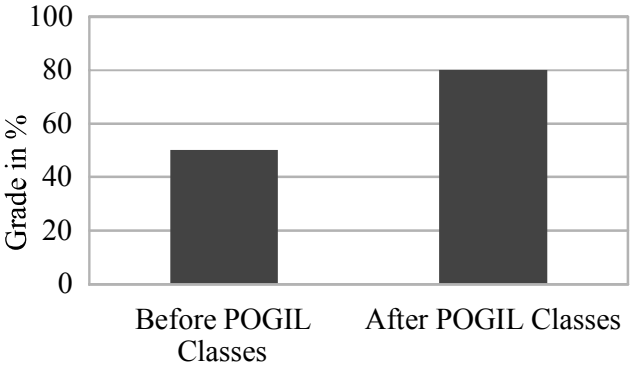

Fig. 2 : Students performance with POGIL

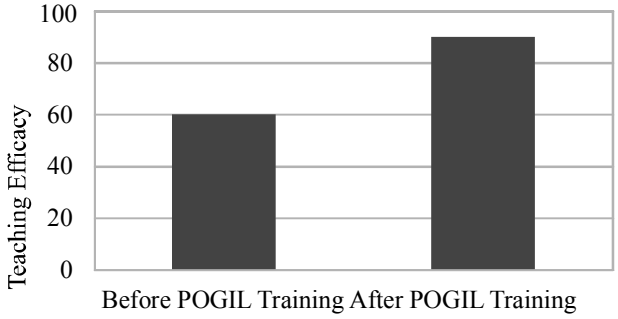

Fig.3 : Faculty teaching efficacy after POGIL training

Received a similar response from faculty as they also from the same generation as the students except that they had completed Master‟s degree. The faculty looked at it as a teaching tool as their main role is teaching and hecne a very big reception for this POGIL methodology. They were excited about as they were able to solve the complex problem themselves. However whent they were given the task of writing POGIL inquiry questionaries for their choice 50% trivial question were their choice which will not inflame critical thinking. POGIL Inquiry questions were given to them to make them to come up with their own inquiry questions for their course. Reflective practice followed by such faculty after their induction period made them self initiaors and hence performance improveemnt of themselves. Internalizing the meaning and the values to accreditation process rather than focussing systems and process will never be a failure though it takes time to implement.

5. Conclusion

In this case study, PO-3 was taught explicitly to final year project phase students for their project accomplishment and appreciative fresh faculty to run through their newfound requirements. The new term open- ended was learnt by both faculty and students and In particular, it gave students the ability to design, assemble, implement and troubleshoot the project which they will encounter in industry environment. Surveys were used to ascertain students‟ insights on acquisition of POs. The feedback from students on POGIL for PO acquisition suggested two things i) the faculty has to ascertain in each course delivery the POGIL questions makes connection with their previous learnt concept. The assessment of new talents acquired by the faculty suggested three things i) solving complex problem can never be a problem for anyone with interest ii) intervention from their seniors who are competent in their domain is required. iii) Faculty really needs to spend time for preparing complex problems and several iterations are needed to make it real open ended. While Australia and other countries have initiated their research on outcome based education and POs in 1990s, India has started very recently in 2010s but started jumping directly into assessment and hence lot of misconceptions about PO among faculty themselves. Hence internalization is needed as a first step to be successful in PO implementation which comes only through suitable instructional methodology.

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