# Massive Project Based Learning through a Competition

## Impact of and Insights from the e-Yantra Robotics Competition (eYRC - 2013)

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***Abstract*—Embedded systems and robotics are interdisciplinary and have a wide range of applications, making them ideal subjects for sparking innovation and creative thinking in engineering students. One way to teach these subjects to students across the country is through distance education. However, as hands-on experiments are a major part of such courses to be effective, and since most colleges lack robotics labs, such attempts have proven to be ineffective. By combining aspects from on-line distance education, multimedia content dissemination, and a step-by-step approach to impart Project Based Learning, e-Yantra Robotics Competition(eYRC) addresses this challenge. One hundred and sixty teams of four members each were provided with: (i) a real-world problem abstracted as a theme, (ii) a robotic kit along with accessories to implement a solution to a given theme, and (iii) tasks with associated templates to train them on the various steps of a project life cycle over the 4-month duration of the competition. Results show that 94% of the teams gained basic knowledge of embedded systems and robotics, with 60% successfully implementing a solution on the robot and 24% exhibiting creativity and critical thinking skills in addition.**

***Index Terms*—Project Based Learning(PBL), Robotics competition, Distance education, Embedded systems, e-Yantra**

## I. Introduction

Hands-on experiments are essential for engineering students to be industry-ready when they graduate. Engineering students in India lack the experience of Project Based Learning (PBL) due to the lack of lab infrastructure and trained teachers to mentor them. Given that robotics and embedded systems are subjects that are interdisciplinary, are increasingly popular, and have a wide range of applications, our work was motivated by the desire to provide opportunities to students to implement projects which help them apply their minds to solving real-world problems.

Distance education efforts to reach the masses have been shown to be effective[1]. But replicating this perceived success in the context of courses that have a large practical hands-on component has remained a challenge. For instance, through the Distance Education Program (DEP) many IIT Bombay courses have been streamed to classrooms across the country. While courses that are theoretical or require programming assignments can be taught effectively in the distance education mode, courses such as embedded systems were not effective as hands-on project implementation typically constitutes a major part of the course.

e-Yantra Robotics Competition(eYRC) is an initiative of the e-Yantra project to expose students in engineering colleges across India, most of whom do not have access to robotics labs, to experiment with a robot and implement a solution to a given problem. The competition combines aspects from distance education and PBL methodology such that student teams distributed across the country can be effective participants. It comprises of:

i Self-paced video tutorials to impart basic concepts and introduction to micro-controller programming are given to participating teams.
ii A set of problems, each defined as a "theme" in the form of a rule book with complete details on arena preparation and constraints on the solution to be implemented are defined. Typically four themes are created and each theme is assigned to a group of teams.
iii A robotic kit complete with accessories to implement a solution to a given theme is shipped to each participating team; participants incur minimum expenditure, for example to print the arena design on a flex sheet.
iv A step-by-step methodology proven effective in helping students implement course projects in the embedded systems course taught at IIT Bombay is used to engage with teams periodically to guide them through different stages of the project.

The competition runs over a period of 4 months and consists of a sequence of "tasks" through which students are evaluated. Each task is a step in the project life cycle: theme analysis, implementation analysis, video demonstration, and report & code documentation. We map the outcomes of the tasks to level of achievement metrics such as basic knowledge, application of knowledge, critical analysis, and extension of knowledge. By analysing the performance of the teams in the tasks along these metrics, we answer the question: **How useful was the competition in imparting knowledge in embedded systems and robotics to the teams?** This question addresses the *impact* of the competition. We then set out to answer: **How easy was it for students to learn the concepts and then implement a solution on the robot?** We analyse the difficulty levels of the four competition themes

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as well as the outcomes and feedback of various sub-groups of teams participated in the competition. These analyses shed light on the *effectiveness* of the competition. In the next section we present a survey on related work. In section 3 we outline the structure and format of the competition. Section 4 presents the impact analysis considering the learning outcomes across all the four themes. Sections 5, 6, and 7 deal with the effectiveness analysis. In Section 8 we present the conclusion summarizing the results of the impact and effectiveness analyses.

## II. Related Work

Pedagogical research in engineering education has shown the importance of Project Based Learning (PBL) in creating industry-ready engineers[2][3]. Research in this area[4][5] points to the fact that even though PBL has no direct bearing on student grades, it has impact on development of required skills. We discuss the various ways in which PBL is delivered below:

***PBL in a classroom:*** In[6] PBL was achieved using a structured laboratory component and a game based project to teach a final year course on embedded electronics systems. Application of PBL increased the level of engagement and learning outcomes for students enrolled in the course. Imparting PBL in a course by incorporating a competition as a course project has also been tried. This model is a mix of traditional classroom lectures and a team-based project. Typically the project component of the course is modeled as a competition. This model covers both theory and practical components[7][8]. Challenges in this model include: (i) providing the correct weightage to the theory and practical aspects of the course and (ii) allowing adequate time for implementing an innovative solution to the problem assigned through the competition[9][10]. Research-problem oriented competitions used in classrooms have been found to promote the development of robotics technologies in[11]. Such competitions benefit students, academia, industry, and society at large as students learn key engineering concepts and are rendered industry-ready.

Thus, while PBL is effectively implemented in face-to-face classrooms through games/competitions built into courses, increasing the number of students and the geographical reach are primary factors addressed by eYRC.

***PBL through a stand-alone competition:*** In this model, the competition organizer defines a problem statement that is solved by students in a self-learning mode. Students do not have any feedback or guidance from the organizers during the competition. Given that only a few teams emerge as winners in these competitions, most of the students are left out, not learning much from participating in the competitions. Impact studies in this model are based on either a set of questions, asked to students before and after the competition[12][13] or on improved performance in their college courses after the competition[14]. While most of these studies claim positive impact of PBL through the competition on student performance, most analyses reported have small number of students, again a limiting factor that eYRC strives to overcome.

***PBL in online courses:*** Through Massive Open Online Course (MOOC)[15] education is delivered to large number of students, professionals and hobbyists in distance education mode. Research conducted on a MOOC based course,"Circuits and Electronics" by edX[16] shows a major drawback of MOOC in the form of huge number of drop-outs (difference between number of students registered and those who complete the course). Considering active participation of students on the discussion forum and completion rate of assignments, result of this study shows that the impact factor of this MOOC was very low. In[17], on-line courses having to deal with hardware components are found to have serious limitations in the form of restrained resources, teacher-student interaction, curriculum design and evaluation/assessment. Online labs have a wide reach and allow students to do experiments over the Internet[18]. However, such virtual labs provide learning in a simulated system rather than through hands-on experiments using robots.

In eYRC the learnings from the various approaches and practices discussed above are combined – it uses a *competition* in which students implement a solution on an educational FirebirdV *robot* conducted *on-line* to impart PBL in a step-by-step manner.

## III. e-Yantra Robotics Competition(eYRC): Structure and Format

Steps in the competition are briefly described below:

1 **Registration:** Students register as a team of four at the competition portal. Students from any branch and year of study of an engineering college are allowed to form teams.

2 **Time slot booking:** Time slots of one-hour duration each are scheduled over 14 days. Student teams book a convenient slot for taking the selection test on a First Come First Serve (FCFS) basis.

3 **Selection test:** All four team members appears for an on-line selection test at their booked time slot. Each member is given a different test and login time for each team member is recorded at a back end server. Each test is of 30 minutes duration. Average score of the 4 members is used to select the team.

4 **Selection process:** Given that there were 4 themes, e-Yantra restricted the maximum number of teams from a given college to 4. With this constraint, based on the performance of the teams, 143 teams were selected using a cut-off score in the selection test. In order to be inclusive, 17 teams were selected from regions, which had low rates of participation, even though their scores were below the cut-off score, referred to as the ***Bottom-17*** in the rest of this paper. Thus, a total of 160 teams were selected for participation in the competition.

- **Assignment of themes:** Based on the discipline of study of the team members, teams were assigned themes. For example, teams with students of mechanical engineers as members were assigned the fruit-plucking theme (Refer to Table III for descriptions of the themes in eYRC-2013), as the main challenge of this theme is designing and building an artifact to pluck and collect the fruits. Care was taken to ensure that teams from the same college were assigned different themes. Overall, a particular theme was assigned to 40 teams. Thus we had 4 themes to serve 160 teams.

5 **Competition:**
- **Launch:** A Robotic kit containing appropriate components and rulebook was shipped to each team. A typical robotic kit contains the following: (i) FirebirdV robot along with accessories such as sensors and actuators required to implement a solution to a given theme (ii) video tutorials on concepts of embedded systems and micro-controller programming (iii) rule book, and (iv) manuals.
- **Format:** The competition is conducted using the PBL methodology evolved at IIT Bombay for class projects in the embedded systems course.

6 **Finals:**
- **Selection of Finalists:** Based on the cumulative scores in the tasks, a total of 20 teams, referred to as ***Finalist-20*** in the rest of this paper, were selected to compete in the finals of the competition.
- **Competition:** The finals of the competition was conducted at IIT Bombay. Teams were asked to demonstrate their solution with a twist in the problem. A short film on the systems built by some of the finalist teams may be seen at[19]. A panel of judges, comprising faculty member of IIT Bombay, asked questions to gauge the originality of the solution provided and to assess the contribution of each of the team members in developing the solution. Top 2 teams from each theme were given internship opportunities at IIT Bombay in addition to certificates and cash prizes. All the 160 teams gave their robotic kits to their respective colleges at the end of the competition to seed robotics labs in their colleges. Thus the competition was also used to distribute robotic kits in a meaningful manner.

Figure 1 presents these steps along with statistics on participation at each step.

A competition format involving several tasks, each of which is a step in the project life cycle, is used to evaluate the performance of the teams to ensure that students learn various aspects of implementing a project using the robot. Table I lists these tasks and outlines what is provided by e-Yantra and the responsibilities of the student teams.

Note that unlike other competitions[21] where students are asked to solve a problem and demonstrate their solution, in eYRC, students are continuously engaged and monitored. They are also mentored by e-Yantra helpdesk through a forum where they post questions. Complete details on the competition format are presented in[22].

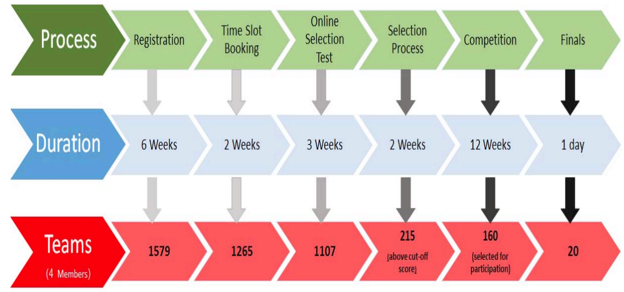


Figure 1: eYRC: Steps and Statistics

## IV. Impact of eYRC-2013

To understand the impact of the competition on imparting effective PBL we first analyzed the performance of the 160 teams across the tasks assigned. As discussed in[22], we have mapped the performance of the teams in the assigned tasks to learning outcomes as specified in Table II. In Figure 2 we present the statistics on the number of teams that completed the various tasks. Note that we have given the percentage break-up as a pie chart with the actual number of teams given as legend.

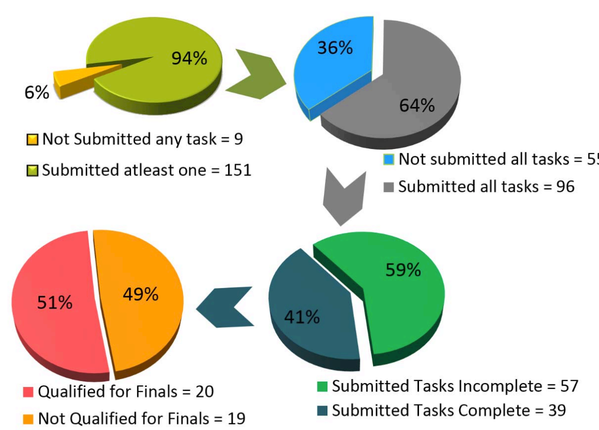


Figure 2: Task-wise break-up of performance of teams

Out of 160 teams, 151 teams submitted at least one task - i.e. 94% of the teams acquired at least the basic knowledge. 96 teams out of the 151, submitted all tasks - i.e., 64% of these teams were exposed to all the tasks through the PBL mode. Out of the 96 teams that submitted all the tasks, 39 had completed all the tasks, i.e., 41% of these teams were successfully trained to implement a project independently. Out of these 39 teams 20 teams were chosen as finalists to compete in the finals of the competition, i.e., 51% of these teams not only successfully completed all the tasks but also have shown the potential to be innovators.

Table I: Details of Tasks assigned in eYRC

| Assigned Task: | Outcomes Imparted/Tested: | e-Yantra provides: | Responsibility of Student Team |
|---|---|---|---|
| **Task 0:** Flex Printing | *Following given instructions | *Flex-design instructions | *Printing flex design<br>*Uploading an image of the flex design. |
| **Task 1:** Theme analysis | Understanding the:<br>*Concepts<br>*Working of robot<br>*Theme assigned | *Video tutorials<br>*Robotic kit with accessories<br>*Manuals<br>*Rule book with the problem specification<br>*Template for theme analysis | *Critically examining the problem.<br>*Answering questions designed to gauge their understanding of the concepts learnt. |
| **Task 2:** Implementation analysis | *Design analysis<br>*Algorithm analysis | *Template to test design analysis and algorithm analysis | *Designing mechanical structure to be added to the robot.<br>* Placement of sensors, actuators.<br>*Considering different options for solving the problem, listing the pros and cons of each option, justifying selection of a particular solution. |
| **Task 3:** Video Demonstration | *Working Prototype for the theme assigned<br>*Video Shooting<br>*Presentation Skills | *Instructions | *Setting up the Demonstration.<br>*Video Recording as per Specifications.<br>*Providing an introductory presentation. |
| **Task 4:** Report and code documentation | *Report Writing<br>*Following Software Documentation Standards | *Instructions to follow software engineering principles<br>*Template for Report | *Specifying Implementation Idea, Design Constraints, Challenges faced.<br>*Modular design of code for reuse by providing: Comments in code, "read me" file with versions of software used and instructions for execution of code. |

Table II: Mapping of Level of Achievement Metrics to Tasks

| Level * | Level Description * | Task | Task Description |
|---|---|---|---|
| **Basic Knowledge** | Recognition and understanding of facts, terms, definitions, etc. | Task 1: Theme Analysis | Critically examining the problem. Answering questions based on the material learnt. |
| **Application of Knowledge** | Use of knowledge in ways that demonstrate understanding of concepts, their proper use, and limitations of their applicability | Task 2: Implementation Analysis | Considering different options for solving the problem, listing the pros and cons of each option, justifying selection of a particular algorithm. |
| **Critical Analysis** | Examination and evaluation of information as required to judge its value to a solution and to make decisions | Task 3: Video demonstration | Making a working prototype.Evaluating the prototype to make the solution more efficient. |
| **Extension of Knowledge** | Extending knowledge beyond what was received, creating new knowledge,making inferences, transferring knowledge to usefulness in new areas of application | Task 4: Report and Code Documentation | Specifying implementation idea, design constraints, challenges faced.Coming up with a sleek design and/or an efficient algorithm. |

*Levels and Description of levels are taken from [20]

Based on the statistics, we map the outcomes to the level of achievement metrics discussed in Table II starting with the highest level of achievement:

**i. Showcased Creativity:** These were the teams that not only demonstrated a working solution but also showcased their creativity in designing an efficient solution. 20 out of 160 teams (12%) exhibited creativity and competed in the finals of the competition as ***Finalist-20***.

**ii. Incorporated Critical Analysis:** Teams which successfully completed all the tasks and solved the problem as specified, were part of this group. These teams learnt the basic concepts and applied those to design the robot by understanding and analyzing the problem statements. Note that the ***Finalist-20*** is also part of this group. 39 (20+19) teams out of 160 (24%) belonged to this group.

**iii. Application of Knowledge:** All the teams who were able to make the robot perform at least part of the solution belong to this group. Thus, the 39 teams who solved the theme and 57 teams that tried to solve the assigned theme but could not complete the theme as desired – 96 teams out of 160 ( 60%) belong to this group.

**iv. Basic Knowledge Gained:** All the teams that submitted at least one task gained basic knowledge. A total of 151 teams (94%) – 96 teams plus the 55 teams who learnt the basic concepts but could not solve the assigned problem and dropped out of the competition – belong to this group.

**v. No Knowledge Gained:** Teams that did not complete even one task belong to this group. 9 out of 160 teams (6%) did not submit any task. These students did not learn

Table III: Description of eYRC-2013 themes

| Themes | Problem statement | Details | Challenges |
|---|---|---|---|
| **Seed sowing** | Detect holes - drop a specified number of seeds in each hole., | Holes are equidistant. Total number of holes is 28. Count of seeds can be 0, 1, 2 or 3 .<br>Table specifying the number of seeds to be dropped is given at the time of demonstration. | Building an artifact to drop given count of seeds.<br>Creating generalized code to take string input and fill holes according to it. |
| **Weeding** | Detect plants and weeds based on size. Uproot weeds and place them in the designated deposition zones. | Position of plants and weeds and distance between plants and weeds are variable.<br>Maximum number of weeds is: 28. | Detecting plants and weeds based on height.<br>Gripping mechanism for picking up weeds and the dropping mechanism. |
| **Fertilizing** | Detect plants specified in a tuple of sequence numbers, belonging to one category, and drop fertilizer pellets.Repeat for all tuples given. | Placement of plants in each category and order in which categories should be fertilized are variable.<br>Maximum number of categories is 3,each having 2-4 plants. | Arena traversal and fertilizing plants in correct order based on categories specified and dispensing pellets. Complex programming for optimal traversal. |
| **Fruit Plucking** | Distinguish ripe fruits from fruits based on their size. Pluck ripe fruits and place them in the designated deposition zones. | Placement and count of ripe and unripe fruits are variable.<br>Maximum number of ripe fruits can be: 36 | Detecting ripe and unripe fruits. and plucking the ripe fruits<br>Designing the artifact for plucking fruits placed at different heights. Arena traversal is of medium complexity. |

anything from the e-Yantra Robotics Competition(eYRC). In the following three sections, we present the results of analysis to gain insights on the perceived difficulties and perceived usefulness of the competition.

## V. Effectiveness analysis -Perceived difficulty levels of themes

Competition themes are created using abtractions of real-world problems. As the population densities of cities increase, the phenomenon of Urban Agriculture – where rooftops of buildings may be used for growing plants – is becoming increasingly attractive. In eYRC-2013, four themes that prototype steps in an agriculture process, namely: (i) seed sowing(SS) (ii) weeding(WD) (iii) fertilizing(FR) and (iv) fruit plucking(FP) were each assigned to 40 participating teams. These themes are described in Table III.

Implementing solutions to these themes involve writing code in Embedded-C to: (i) collect data from sensors, (ii) based on this to implement necessary action through an artifact built on the robot, and (iii) traverse the entire arena to complete the given task efficiently.

Table IV: Difficulty levels of Themes

| Themes | Difficulty Levels | | |
|---|---|---|---|
| | **Sensing** | **Artifact design/Operation** | **Traversal** |
| Seed Sowing | Low | High | Medium |
| Weeding | Medium | High | Low |
| Fertilizing | Low | Medium | High |
| Fruit Plucking | Medium | High | Medium |

In Table IV we present the difficulty level of each of the themes under the three categories, classified as:
**(i) Sensing** - includes appropriate placement and calibration of the sensors.
**(ii) Artifact design/Operation** - involves designing and manipulating the artifact built on the robot to carry out the appropriate action.
**(iii) Traversal** - includes finding an optimal path/efficient algorithm to complete the task.

From Table IV, we can infer that while difficulty levels vary across the three categories, we have tried to balance the overall difficulty level across the four themes. We expected fruit plucking theme to be the hardest as it had a high difficulty level in artifact design/operation and medium difficulty levels both in sensing and traversal. We assigned this theme mostly to teams with an inter-disciplinary composition. We expected the weeding theme to be the easiest, as it involved a gripping mechanism to pick up the weeds which was similar to "pick placer"[22], a theme from eYRC-2012, the pilot edition of the e-Yantra Robotics Competition(eYRC). Based on this assumption 8 out of the ***Bottom-17*** teams were assigned the weeding theme. Figure 3 presents the percentage of teams not completing the tasks in each theme. As expected, fruit plucking (FP) had slightly higher drop out rates compared to seed sowing (SS) and fertilizing (FR). To our surprise, more number of teams dropped out from the weeding (WD) theme across all the tasks. After evaluating Task 3 (Video demonstration) and Task 4 (Code and documentation), the number of teams(out of 40/theme) that had a fully working solution in the four themes was as follows:

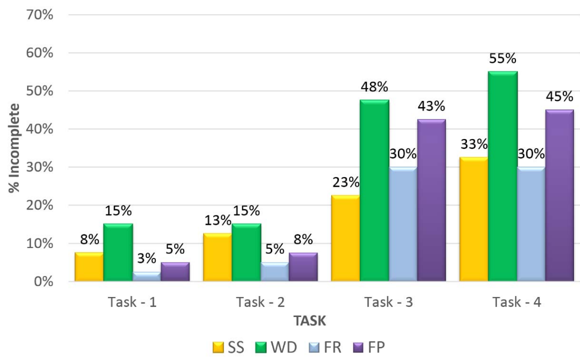


Figure 3: Representation of the teams not completing tasks in each of the themes

Seed sowing - 13; Weeding - 4; Fertilizing - 11; Fruit plucking - 10. Here again, we find that the weeding theme had the least number of teams with working solutions.

Two factors could influence this outcome: (i) difficulty level of the theme (ii) readiness/quality of the teams assigned to these themes. In weeding, even though the basic gripper mechanism is easy to implement, it had some unique challenges. Placement of weeds on the arena was random; in addition, the inter-distance between the plants and weeds was variable. This demanded accuracy of sensing and manipulation of the gripper to align it properly. Fine-tuning the sensors is tricky as external lighting can affect the sensors and alignment of the gripper is affected by robot behavior that depends on factors like battery level. Thus, weeding proved to be more challenging than we had assumed.

The fact that 8 teams from the ***Bottom-17*** were assigned this theme - Two dropped out and none of the other six teams completed all the tasks - compounded with the difficulty level of the problem, resulted in only 4 teams implementing a working solution.

## VI. Effectiveness measured in the *Bottom-17*

In order to provide opportunities to teams from regions with low representation, we included 17 teams even though their selection test scores were below the cut-off score. We present the analysis of this sub-group, referred to as ***Bottom-17***, to understand the impact of the competition on this group.

In Figure 4, we present the statistics on the number of teams that completed the various tasks. Out of 17 teams, 15 teams submitted at least one task - i.e. 88% of the teams acquired at least the basic knowledge. 9 teams out of the 15, submitted all tasks - i.e., 60% of these teams were exposed to all the tasks through the PBL mode. Out of the 9 teams that submitted all the tasks, 3 had completed all the tasks, i.e., 33% of these teams were successfully trained to implement a project independently. Out of these 3 teams 2 teams were chosen as finalists to compete in the finals of the competition, i.e., 66% of these teams not only successfully completed all the tasks but also have shown the potential to be innovators.

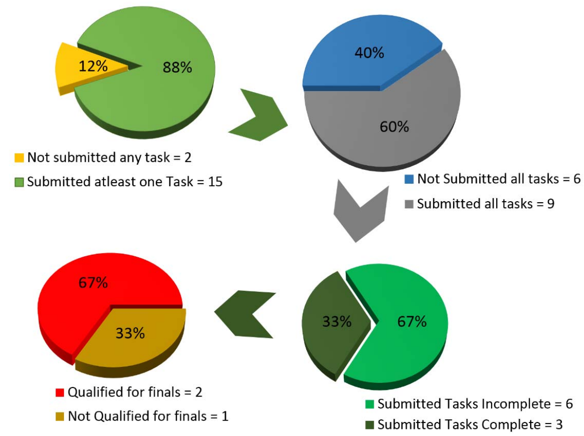


Figure 4: Task-wise break-up of performance of ***Bottom-17*** teams

Based on the statistics, we map the outcomes to the level of achievement metrics discussed in Table II starting with the highest level of achievement:

**i. Showcased Creativity:** Two out of 17 teams (11.7%) exhibited creativity and competed in the finals of the competition as ***Finalist-20***.

**ii. Incorporated Critical Analysis:** These teams learnt the basic concepts and applied those to design the robot by understanding and analyzing the problem statements. Note that the ***Finalist-20*** is also part of this group. (2+1) teams out of 17(17.6%) belonged to this group.

**iii. Application of Knowledge:** All the teams who were able to make the robot perform at least part of the solution belong to this group. Thus, the 3 teams who solved the theme and 6 teams that tried to solve the assigned theme but could not complete the theme as desired – 9 teams out of 17 ( 52.9%) belong to this group.

**iv. Basic Knowledge Gained:** All the teams that submitted at least one task gained basic knowledge. A total of 15 teams (88%) – 9 teams plus the 6 teams who learnt the basic concepts but could not solve the assigned problem and dropped out of the competition – belong to this group.

**v. No Knowledge Gained:** Teams that did not complete even one task belong to this group. 2 out of 17 teams (12%) did not submit any task. These students did not learn anything from the e-Yantra Robotics Competition(eYRC). In Table V, we provide the comparison of these results to the overall impact analysis presented in Section IV. Even though the levels of achievement across all the categories are lower than the overall levels, two of these teams were placed in the ***Finalist-20***, one ranked 4th in the fertilizing theme and the other ranked 5th in the fruit plucking theme, proving the effectiveness of the competition in imparting PBL.

Table V: Comparison of results

| Level of Achievement | Over-all (160 teams) | *Bottom 17* (17 teams) |
|---|---|---|
| Basic knowledge | 94% | 88% |
| Application of Knowledge | 60% | 52.9% |
| Critical Analysis | 24% | 17.6% |
| Creativity | 12% | 11.7% |

## VII. Perceived effectiveness of the competition

At the end of the competition, participants were asked to provide feedback. Out of the 640 students who participated in the competition, 465 filled the feedback form. Feedback questions were posed to assess: (i) perceived effectiveness of the competition (ii) efficiency of the helpdesk in clearing their doubts and (iii) ease of use of the competition portal. Participants also provided Yes/No answers regarding prior exposure to embedded systems and robotics. In this section we focus on the analysis of effectiveness of the competition from the feedback received. We analyze the ratings of participants on a five point Likert scale (from Strongly Disagree to Strongly Agree) of a statement that addresses participants' perception of effectiveness of the competition: *"I found that the competition format helped me to understand concepts in embedded systems and robotics and apply the concepts to solve a practical problem"*. With reference to Figure 5, 94% have chosen *strongly agree* or*agree* with 3% choosing *neutral* and 3% choosing *disagree*.

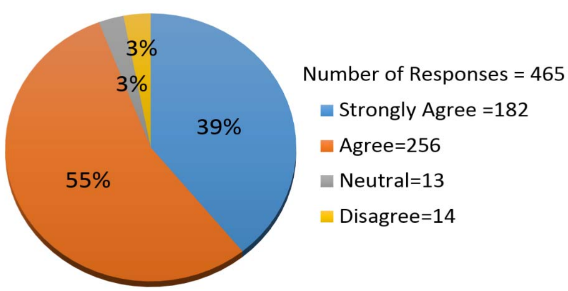


Figure 5: Overall Feedback - Post Competition

Figure 6a examines whether prior exposure to embedded systems and robotics has an impact on the perception of the participants. Out of 465 participants, 235 had answered *No* to prior exposure and the rest 230 answered *Yes*. We find that higher percentage of the participants with prior exposure have chosen *strongly agree* compared with participants with no prior exposure. However, only 3% from either group have disagreed. Thus, prior exposure does not seem to affect the perceived effectiveness of the competition.

To understand whether perceived effectiveness varies with achievement levels in the competition, we analyzed the responses to the same statement from the ***Bottom-17*** and ***Finalist-20*** sub-groups. Results are presented in Figure 6b and 6c. We find that in both sub-groups no one chose the *disagree* option and only one chose *neutral*. Thus,

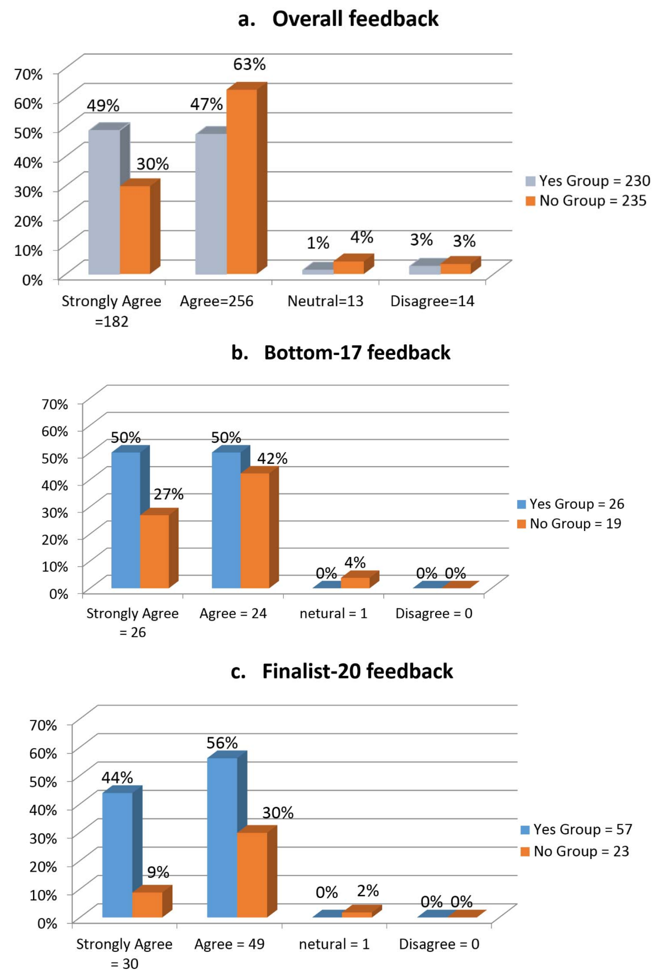


Figure 6: Perceived Effectiveness Analysis

irrespective of their achievement levels in the competition, participants have expressed high levels of satisfaction in understanding concepts in embedded systems and robotics and applying the concepts to solve a problem.

## VIII. Conclusion

Given an opportunity, students from engineering colleges across the country are capable of implementing innovative solutions to solve every-day problems - this was the premise under which the eYRC model and methodology were designed and the themes were selected. Our goal was to provide opportunities to students, who do not have lab facilities or mentors, to experiment with hands-on project implementation using robots.

From the analysis of learning outcomes of the 160 teams participated, we find that 94% of the students who participated in the competition gained basic knowledge of embedded systems and robotics. Out of these about $2/3^{rd}$ of the teams could apply their knowledge and implement solutions on the robot. Approximately $1/3^{rd}$ of the teams participated exhibited creativity and critical thinking skills where they not only devised a solution but also worked on efficient ways to design and implement their solution. These results prove that the competition is useful in delivering PBL to the masses - student teams distributed all over the country. To understand how easy it was for teams to learn and apply concepts in this online competition, we analyzed the difficulty levels of the competition themes and their impact on the outcomes. We found one instance where our assumption about the difficulty level of the theme turned out to be false and we realized why it was. Results of this analysis will be helpful in designing themes for the future editions of the competition to achieve even better levels of learning.

Results of analysis on the performance of the ***Bottom-17*** sub-group, chosen for participation to be inclusive, assert the effectiveness of the competition in imparting PBL as performance of this sub-group closely resembled that of the overall performance of the teams. In addition, two teams from this sub-group excelled and moved into the ***Finalist-20*** sub-group. Analyses of the feedback received from participants post competition on the effectiveness of the competition format show that the competition is perceived to be effective in delivering PBL irrespective of whether the participants had prior knowledge in these subjects or whether they belonged to ***Bottom-17*** or ***Finalist-20*** sub-groups.

The competition model and methodology have also been successfully used to train 51 teacher teams, each having four members, from engineering colleges through the e-Yantra Robotics Teacher Competition (eYRTC) as part of the e-Yantra Lab Setup Initiative[23]. Around 75 teams of teachers from all across the country will be participating in the next edition of eYRTC, scheduled to be launched in the second week of August 2014, making this competition model truly scalable to reach the masses.

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## References

[1] S. Krithivasan, M. Baru, and S. Iyer, "Experiences with an interactive satellite based distance education program," *Society for Information Technology and Teacher Education, (SITE) 2004*, March 2004.

[2] J. E. Mills and D. F. Treagust, "Engineering education - is problem-based or project-based learning the answer?" *In Australasian Journal Of Engineering Education*, 2003.

[3] "Stanford pbl lab." [Online]. Available: http://pbl.stanford.edu/Research/ResearchILE.html [Accessed: 24th September,2014]

[4] A. S. Blicblau and D. J. Richards, "Undergraduate engineering project work," *Proceedings of the 2010 AaeE Conference*.

[5] J. Strobel and A. van Barneveld, "When is pbl more effective? a meta-synthesis of meta-analyses comparing pbl to conventional classrooms," *Interdisciplinary Journal of Problem-based Learning*, vol. 3, pp. 44–58, March 2009. [Online]. Available: http://dx.doi.org/10.7771/1541-5015.1046

[6] B. R. Wildermoth and D. D. Rowlands, "Project based learning in embedded systems: a case study," *Proceedings of the AAEE Conference*, 2012.

[7] C. Almeida, "Practical experience teaching embedded systems," 2008.

[8] D. Davcev, B. Stojkoska, S. Kalajdziski, and K. Trivodaliev, "Project based learning of embedded systems," *In 2nd WSEAS International Conference on Circuits, Systems, Signals and Telecommunications (CISST'08)*, January 25-27 2008.

[9] R. R. Murphy, "A strategy for integrating robot design competitions into courses in order to maximize learning experience and promote intellectual development," *In IEEE Robotics & Automation Magazine*, vol. 8, pp. 44–55, 2001.

[10] M. Calnon, C. M. Gifford, and A. Agah, "Robotics competitions in the classroom: enriching graduate-level education in computer science and engineering," *In Global Journal of Engineering Education, WIETE*, vol. 14, no. 1, pp. 6–13, 2012.

[11] C. J. Chung and L. Anneberg, "Robotics contests and computer science and engineering education," *In 33rd ASEE and IEEE Frontiers in Education Conference*, pp. 8–14, 5-8 November 2003.

[12] C. C. Hendricks, M. Alemdar, and T. W. Ogletree, "The impact of participation in vex robotics competition on middle and high school students interest in pursuing stem studies and stem related careers." *In American Society for Engineering Education*, 10-13 June 2012.

[13] E. Trudell and C. Chung, "Development of methodologies to assess the impact of autonomous robotics competitions in science,technology, engineering, and math education," *In Proceedings of the International Technology, Education and Development Conference (INTED 2009)*, 9-11 March 2009. [Online]. Available: http://www.robofest.net/STEMedu.htm [Accessed: 24th September,2014]

[14] M. S. Raghav, S. Jain, and S. K. Saha, "Robotic competition based education in engineering (roc-bee)," *In National Conference on Mechanism Science and Technology: from Theory to Application, Proceedings of NCMSTA'08 Conference*, pp. 1–11, 13-14 November 2008.

[15] "Massive open online course." [Online]. Available: http://mooc.org/

[16] L. Breslow, D. E. Pritchard, J. DeBoer, G. S. Stump, A. D. Ho, and D. T. Seaton, "Studying learning in the worldwide classroom research into edx's first mooc," *Research and Practice In Assessment*, vol. 8, September 20-21 2013.

[17] X. Chen, D. R. Barnett, and C. Stephens, "Fad or future: The advantages and challenges of massive open online courses (moocs)," *Research-to Practice Conference in Adult and Higher Education*, September 20-21 2013.

[18] R. Sell, S. Seiler, and D. Ptasik, "Embedded system and robotic education in a blended learning environment utilizing remote and virtual labs in the cloud, accompanied by robotic homelab kit," *In iJET*, vol. 7, no. 4, December 2012.

[19] "Homepage of e-yantra project." [Online]. Available: http://www.e-yantra.org/ [Accessed: 24th September,2014]

[20] D. C. Davis, R. W. Crain, D. E. Calkins, K. L. Gentili, and M. S. Trevisan, "Categories and levels for defining engineering design program outcomes," *In Transferable Integrated Design Engineering Education, Washington State University.* [Online]. Available: http://tidee.cea.wsu.edu/publications/ [Accessed: 24th September,2014]

[21] "List of robotics competitions." [Online]. Available: http://robots.net/rcfaq.html [Accessed: 24th September,2014]

[22] S. Krithivasan, S. Shandilya, K. Arya, K. Lala, P. Manavar, S. Patil, and S. Jain, "Learning by competing and competing by learning - experience from the e-yantra robotics competition," *In IEEE Frontier In Education (FIE), 2014*, October 2014.

[23] S. Krithivasan, K. Lala, K. Arya, S. Shandilya, P. Manavar, S. Patil, and S. Jain, "e-yantra lab setup initiative - sustainable knowledge creation and scalable infrastructure creation at engineering colleges," *In IEEE Frontier In Education (FIE), 2014*, October 2014.