Project-Based Learning in Digital image processing course

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Abstract—**The current paper presents project/problem-based learning (PBL), equipped with contemporary technologies as a strategy to revolutionize traditional teacher-centric classrooms to student centric systematic and innovative learning. Understanding the core concepts of image processing techniques and identifying its applicability in real-time scenarios requires in-depth visualization. Classroom lecturing is trivial for students to appreciate the significance of image processing systems. On learning through real-world projects, nearly every aspect of students' experience change. Learners pursue the subject knowledge on their own with their own meaning, under the guidance of an instructor. Instructors design the project as a framework for learning, subsequently students wind up using technology to access and analyze information in all dimensions possible. The article presented comprehends important aspects of PBL and illustrates the digital image processing sessions carried out using the proposed approach.**

Keywords-Problem based learning, project based learning, digital image processing, engineering education Introduction (Heading 1)

I. Introduction

Learning core concepts in digital image processing involves more visualization along with understanding. The students need to appreciate and reason the need for application of every intermediate operation on the image. Understand the concept of acquiring, storing and processing the digital image plays a crucial role in learning processes. An exposure to practical implementation parallel to lecturing suits best in teaching the course.

Mostly, the course is supplemented with laboratory experiments. The experiments usually involve all the basic pre-processing operations to store, manipulate and enhance the images. The last few sessions of laboratory comprises of few advanced topics in color image processing and restoration. Limiting the assessment only to laboratory experiments is trivial. The predefined experimental sessions limit to 'knowledge' and 'comprehension' levels of Blooms taxonomy. Application of knowledge taught, usage of problem solving methods and evolving new ideas from learnt concepts is constrained. The course needs to promote analytical skills, ability to recognize trends and evaluate the outcomes. Motivation towards gaining more insights into image processing is achieved by adapting to PBL.

PBL, alternatively known as inquiry-based learning (IBL), one of constructive methods developed during early 1960s popularly in US and Canada for medicinal courses [2]. PBL facilitates students to gain knowledge and skills by investigating and exploring solutions to complex problems or challenges. The notion of PBL represents a learning philosophy than the details in organization of curriculum. PBL fosters new epistemologies in the creation of knowledge and innovation. The students work over extended period to time to accomplish the task. The approaches are increasingly implemented in engineering education, recognizing the benefits of active learning and importance of engineering students developing professional skills [3].

Digital image processing being an important research area, it is required to encourage students towards development of innovative projects based on image processing. Applications are tremendously wide making it very difficult to provide a comprehensive study within the class hours. The past experience of instructors using traditional lecturing methods indicated that students' inquisitiveness, in-depth enquiry and propel to study advance image processing tools declined. Students were unable to appreciate the assets of image processing techniques, reason the need and applicability of a particular enhancement/ restoration technique and inspect the trends of image processing. The teaching methodology did not incorporate an interesting factor to provoke students towards the course. It was required to integrate a self-study component into traditional classroom learning and drive enthusiasm towards the course. Consequently new teaching methodology based on PBL was experimented. The current paper describes in detail the PBL component added to lecture-centric digital image processing course. An overview of PBL method highlighting its importance in state-of-art education system is presented in section II. Section III outlines implementation of the approach in digital image processing course. The paper also discusses lessons learnt during the first offering of the new course format and outlines future work directions.

II. OVERVIEW OF PBL IN ENGINEERING EDUCATION

The spread of PBL in engineering education around the world has been enabled by factors and motivations that vary significantly across national and international contexts [4, 5]. Evidence suggests that industry demand for professional skills and changes in accreditation procedures have been two primary drivers behind adoption PBL at many institutions [6]. Essential elements of PBL as illustrated in figure 1 include [1]:

- Significant content: Objective being to impart standards and key concepts at the core of academic subjects, the projects focus on important knowledge and skills pertaining to the specific concept.

- Competencies: Students build cutting edge competencies essentially, problem solving, critical thinking, collaboration, communication and creativity/innovation that shall be explicitly assessed.
- In-depth inquiry: Students are engaged in extended rigorous process of investigation, utilization of resources and developing solutions that promote the ability of questioning and reasoning.
- Driving question: Students encounter open-ended questions that help them to understand and find intriguing, which frame their exploration.
- Need to Know: Students understand the importance of knowledge gaining, understanding concepts and application of skills for problem solving and project development.
- Voice and Choice: Students learn to plan the work to meet stipulated timing guidelines, ability to choose a particular product and under-stand its working work guided by the teacher depending on age level and PBL experience.
- Critique and Revision: The method enhances abilities of students to evaluate the quality of their work, leading them to revise or conduct further inquiry.
- Public Audience: Students present their work to other people, beyond their classmates, teacher enriching their vocabulary and presentation skills. Documentation allows the student to develop organization and writing skills.

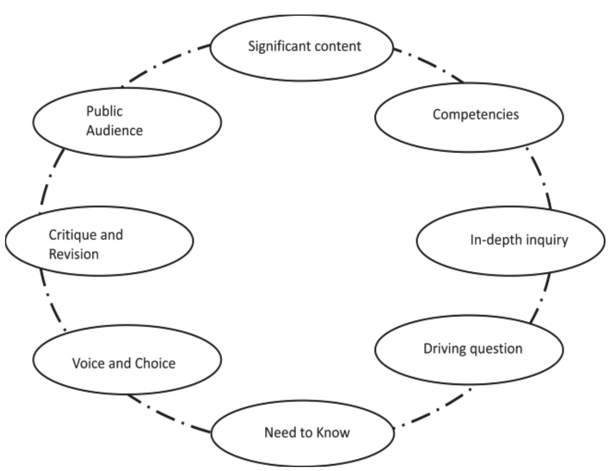

Fig:1. Essential elements of PBL approach

A. Motivation of PBL in engineering education

Engineering educators are motivated to employ PBL by the need to adapt to limited institutional resources that includes time, space, inflexible curricula, while responding to the rapid evolution engineering technology. PBL is useful as a strategy to overcome reluctance to establish new engineering tools in the course of studies. The explosive growth of newer technological tools hinders their study within overloaded engineering program. PBL promotes exposure to a wide choice of simulation/mathematical tools towards development of the project.

Propel towards acquiring professional or non-technical skills in engineering education are due to lack of satisfaction in professional world with graduates' capabilities. Self-study takes the central position in PBL framework and emphasizes the self-responsibilities of the learner for knowledge acquisition [7]. Mark et al. provides an introductory overview of what appear to be the key features of the approach [8].

B. PBL learning principles

Learning principles in PBL model is captured in three approaches: learning, contents and social as shown in figure 2 [1]. Learning is organized around the problem in cognitive learning approach and is carried out in projects. Definition of problem initiates learning processes, places learning in context and bases learning on the learner's experience. Content based learning concerns interdisciplinary learning spanning across traditional subjected-related boundaries and methods. Learning outcome is exemplary to the overall objective of the curriculum. The problem approach supports the relationship between theory and practice by the fact that the learning process involves an analytical approach by using theory in the analysis of problems and problem-solving methods. Social approach is team-based learning where learning takes place through dialogue and communication. Students learn from each other, share knowledge and organize themselves in collaborative learning. The social approach covers participant directed learning, indicating collective tenure of learning processes and problem formulation. PBL being used in various educational systems that represent a wide range of subjects, the concrete models need to be different. It is required to define educational concepts by means of models supported by learning principles beyond concrete educational practices and models [9].

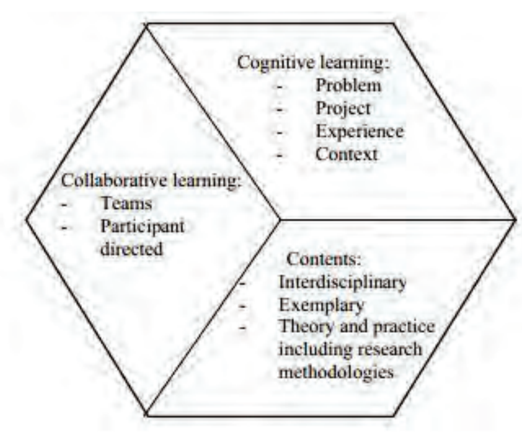

Fig: 2. PBL learning principles

Lecturing continues to be a part of PBL curriculum. The clear difference is that project relates to more of applying the knowledge learnt than objectives based on the content of lectures. The curriculum objectives are re-formulated with more general methodological objectives addressing learning of innovation projects and supporting lectures.

III. PBL IN DIGITAL IMAGE PROCESSING COURSE

Graaff and Kolmos define various problem definitions and project types [10]. Problem definitions belong to either discipline or interdisciplinary projects. Discipline projects are regarded as study projects having clear study objectives that students learn with a predefined scientific knowledge. Interdisciplinary approach is more open-problem projects with solutions known to neither facilitator nor student. These projects are a kind of innovation projects based on collaborative and interdisciplinary knowledge.

The teacher initially identifies problems rightly for the student that is accessible yet challenging enough to simulate the learning process. The problems incorporate most of the basic principles and proceeds towards implementation of more complex algorithms. Examples of innovative project ideas include application of image processing in computer vision, agricultural application, biometrics, medical imaging, microscope image processing and robotics. The projects were formulated in a way that students achieve a well-defined goals under the guidance of course instructor. The goals were achievable via multiple paths.

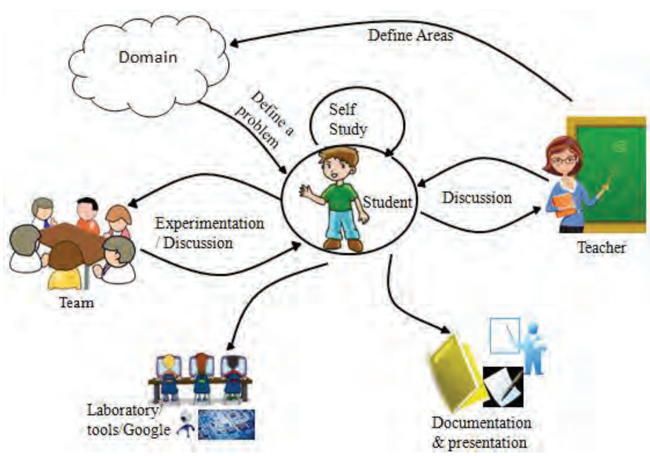

Fig: 3. Flow diagram of activities involved in proposed PBL learning

The students were asked to group themselves into teams of four or less and encouraged to specify their problem within the pre-defined areas. A brief synopsis with a clear description of problem indicating its motivation and expected outcomes is drafted. Synopsis submitted is reviewed by the instructor and is followed by the planning stage by the students. Planning stage involves identification of various processes (such as preprocessing, segmentation, extraction/classification etc.) involved to accomplish the task. Initially, the students prepare a ground work to identify the choice of processes require. Students study papers from high quality publications pertaining to recent developments as a literature survey. The students proceed to implementation stage that involves inter-connection of the above processes and tuning of parameters to meet the expected outcomes. All the problems were solved using custom-designed software. The laboratory sessions assisted the students to get acquainted to the tools. Flow diagram of figure (3) describes the activities involved in the proposed PBL learning.

The projects included the necessity to understand the significance of different stages in an image processing system. Students needed to discriminate various closely related aspects involved in the system. There was a need to interrogate and reason the need for choosing a particular domain of transformation - frequency, spatial or both. Students needed to design a plan for intended product working outside their knowledge base.

Many hardware applications are too complex to be implemented within the stipulated time. Simulation tools including Matlab, Simulink, LabView and Scilab address this challenge by making it easy for students to implement their projects on low-cost hardware platforms. A problem is solved using either coding or modeling. The coder solves the problem by developing an algorithm, setting up decision logic and writing codes. Modeler solves by creating a system diagram highlighting connections and information flows. Using the low-cost hardware, students are allowed to establish a tethered connection with the board to acquire information from input devices like sensors, process the information through an algorithm and send it back to output units like actuators.

The project deliverables consisted of:

- A brief presentation of problem definition and its motivation. The experimental discussions of different viable scenarios are presented using simulation tools/hardware implementation.
- A demonstration of complete, functional system along with experimental results using software/hardware simulation tools.
- A written report describing the problem, its solution and design methodology.

The outcomes of students' participation in PBL included students' use of technology-based vocabulary and a range of outcomes related to answering authentic questions on problem solving, task factors, utilization of technology and indicators of project completion.

The project is accounted for 10% of the total course marks, with the possibility of gaining up to 5% extra points for high quality projects dealing with original problems. Two example problems are outlined below:

A. Virtual mouse system for human computer interface

Fig: 4. Implementation of virtual mouse by tracking finger movement

A virtual mouse is developed as a human computer interface using a webcam and computer vision techniques as shown in figure 4. The user needs to perform a particular gesture as required. A webcam is interfaced with the system to capture and identify the gesture. The system is initially trained for a set of gestures using finger tracking techniques. When the user needs to use the virtual mouse, his gestures are matched with one of the known gestures and opens to a particular application.

The project essentially consisted of four significant steps.

- Taking input from the webcam and converting it into a form that can be processed easily.
- Intercepting the gesture from the input of the webcam.
- Recognizing the gesture from a database of gestures.
- Give corresponding commands for the operations according to the intercepted gesture.

The students were able track movements in real time using the color marker approach. The gesture was recognized and the movement of the marker translated into the movement of the mouse. The project was able to bring in the concept of Human Computer interaction.

B. Attendance system based face recognition

The project involves taking snap shots of a classroom using web cams and processing them to retrieve information necessary for updating an attendance system as shown in figure 5.

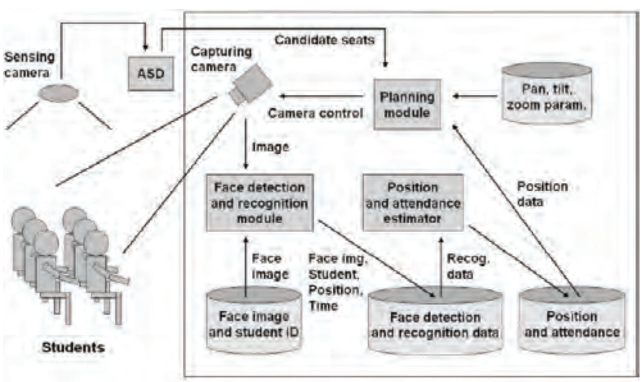

Fig: 5. Automatic attendance system

Four webcam were fixed at four different positions in the class room to take four pictures each containing of a subset of students from the entire class. Faces of students were segmented from images acquired during the class session. The segmented and pre-processed faces are matched against a data base that includes all the students registered for the particular course as shown in figure 6. The matching score is used to update the status of attendance automatically and be available at a common access point.

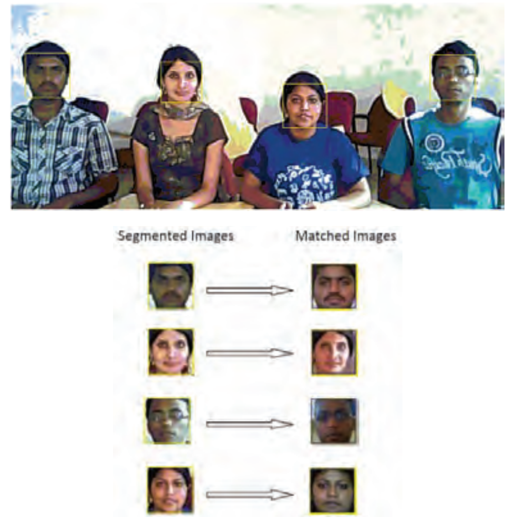

Fig: 6. Segmentation and matching of faces

IV. SURVEY REPORTS

The instructors had experiences of both traditional and PBL formats. The experience indicated that PBL is more favorable with expanded tutor-student relationship, increased motivation and group atmosphere. Feedback from students was collected via anonymous surveys and course evaluation forms. Course end evaluation indicated good learning experiences by the students. The important observations are summarized as follows and figure 8 depicts the skills developed by students through PBL learning:

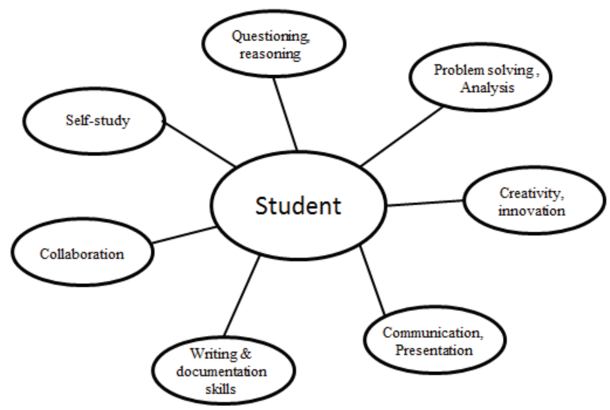

Fig: 8. Skills attainable through PBL learning

For students:

- It's a student-centric approach
- Students found the course more enjoyable and satisfying
- Encouraged greater understanding
- Long term knowledge retention
- Students with PBL experience rated their abilities higher

- Increased the rate of development of image processing based final year under graduate projects

Benefits for instructors:

- Class attendance increased
- Method afforded more intrinsic reward
- Encouraged students to spend more time in studying
- Promoted interdisciplinary interests

The impact created with introduction of digital image processing course for undergraduate students was compared over three years. Initially the course was carried using lecturing sessions marking the class strength of 90 students. Introduction of laboratory component in 2011-12 attracted more students to opt for the course. Integration of PBL component significantly increased the strength to 150 students as indicated in graph of figure 9. The percentage of image processing based undergraduate projects over the same three years shown in figure 10 is indicative of the PBL method's potentiality.

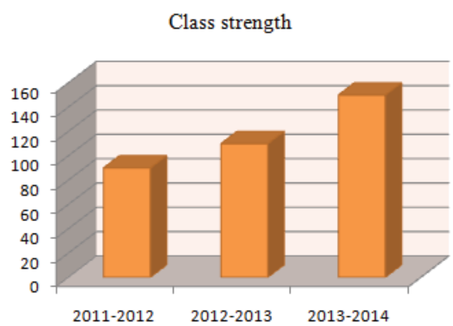

Fig: 9. Rate of increase in class strength for the course

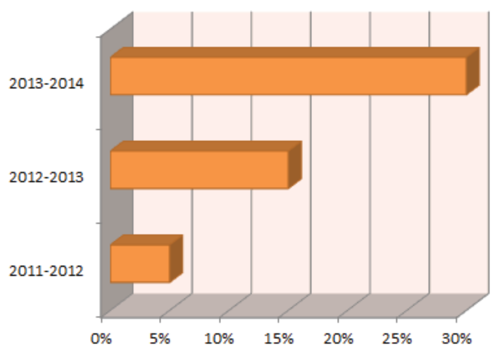

Fig: 10. Pie chart indicating percentage of image processing based UG projects over three years

V. Challenges Faced in PBL Implementation

Despite numerous benefits, PBL approach presents several challenges for the teachers, that include limited instructional resources, students' lack of experience in PBL and their preferences for traditional-structured approach that emphasize passive learning. In addition the organization and administration of PBL is time-consuming.

The first offering of Image Processing course in the new hybrid format has been an intense learning experience for the instructional team. An important aspect of consideration for PBL practice is the level of prior knowledge equipped by the target group. Lecturing being a parallel session, students required time to apply the knowledge learnt in classroom session. PBL takes a lot of time and requires active participation. Meeting timelines pressured the students towards completion and little time was available for comparison and analysis of processes used. The class had over 150 students enrolled and the instructional resources were limited to two course instructors. Direct meeting with instructors frequently was a concern. On drifting into detailed experimentation, students who arrive at wrong interpretation waited for the tutors to answer their questions instead of collaborative efforts.

Another factor of constriction in PBL practice arise between allowing students to define their own learning goals and students asking for coherence between other project groups. Experience showed that students get wary if their learning objectives were different than other groups of their cohort. It was a difficult task for the instructor to balance the idea of students following their own interests while ensuring certain coherence with rest of the cohort.

Project being developed as a team-work demanded rich instructional resources to assess individual contribution. Basic principles and reasoning abilities were tested only through viva-voce.

VI. Conclusions

PBL improved student's ability to relate abstract concepts presented in theoretical and laboratory sessions with concrete experimental setup. Proponents of PBL tout its ability to foster strong learning outcomes even under robust misconceptions in mental models. PBL-based digital image processing course facilitated hands-on experience, participation in collection and analysis of data and aided significantly to attain professional skills. Collaborative work and documentation promoted comprehending skills. The student feedback supported the fact that PBL transforms learning into a more active, student-driven experience, using technology tools for inquiry, collaboration, and connection to the world beyond the classroom.

VII. Future Work

PBL based teaching endeavor propounded that the basic assumption of „prior knowledge' of the problem defined was an important factor affecting the quality of projects developed. The experience revealed the need for sufficient time to carry out literature survey. A survey around the defined problem required crucial attention for successful completion. Contemplating on its need, we propose to award 5% of total course marks to a report on problem defined and 10% to realization of the project.

The experience suggests that PBL implementation can be improved by evaluating the functioning of learner on a regular basis. In addition, learning and assessment needs to be better integrated with consistency of assessment instruments with learning principles. A key to successful implementation relies on designing a learning environment that stimulates students towards constructive learning.

VIII. ACKNOWLEDGEMENT

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