Problem Based Learning in Engineering Design

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Abstract
Design has traditionally been an important part of an engineer’s training. The initial Engineering Design course in second year undergraduate engineering degree play an integral part in combining the learned knowledge and promote problem solving proficiency. Engineers Australia (Formerly the Institution of Engineers Australia) outlines, soft skills and social proficiencies as a key competency in the accreditation framework. Furthermore the Australian engineering competency standards gives design a significant weight in its evaluation criteria, requiring engineering curriculum to have significant design course experience (2004). Thus engineering design pedagogy including assessment and evaluation strategies are of an increased emphasis for educators. This paper describes the application of problem based learning in an undergraduate preliminary engineering design course with an emphasis on student learning.

Keywords: Instructivist, PBL, Reflective practice, Strategy, Engineering Design,

1. INTRODUCTION

There is currently worldwide interest in improving the quality of engineering education and in some instances governments have intervened to assess the quality of teaching and learning across the spectrum of subjects [1]. Globally, attention is increasingly being paid to the quality of teaching and learning in higher education. Higher education teaching is becoming more professionalised with some countries setting up accreditation bodies to ensure competencies [2]. Similarly companies are increasingly pressured by global competition and rapid changes in technology to become more flexible and adaptive. The Australian national review of engineering education identified the need for a cultural shift to recapture the societal relevance of the undergraduate engineering curriculum, and the engineering profession itself [3]. The quality of student learning is directly although not exclusively related to the quality of teaching. Therefore, the first and most promising way to improve learning is to improve teaching writes [4].

Change is constant and everywhere [5] modern society is characterized by a rapidly expanding base of knowledge and expertise, such that many students can not be expected to be cognisant of all of the knowledge in their chosen area of learning, [6]. Whilst trying to incorporate more “human” skills into their knowledge base and professional practice, today’s engineers must also cope with continual technological and organisational change in the workplace. In addition they must cope with the commercial realities of industrial practice in the modern world, as well as the legal consequences of every professional decision they make[7]. The challenge of preparing engineering graduates for a fast changing work environment calls for the development of thinking programmes [8].

On their first graduate placement many engineers are frequently challenged with functional realignment where graduate engineers are working in unfamiliar terrain as part of multi-disciplinary multidimensional teams, usually rescued by there process skills which are “soft” skills used in the application of knowledge. Although traditional engineering design courses train student engineers to tackle design problems, the jury is still out on teaching methodology. [9] reports on research into the development of generic skills, key engineering competency and problem solving in traditional engineering courses in (higher education) with key findings were engineering courses do not provide graduates with the level of communications or managerial skills which industry, professional associations, governments or indeed the graduates themselves, consider necessary. However given that our perceptions do not come simply from the objects around us, but from our past experience as functioning purposive organisms [10]. The degree to which students develop soft skills determines how they solve problems, write reports, function in teams, self-assess and do performance reviews of others, go
about learning new knowledge, and manage stress when they have to cope with change. Many instructors intuitively believe that process skills are important, but most are unaware of the fundamental research that provides a foundation for development of the skills. Their efforts to help their students develop the skills may consequently be less effective than they might wish [11]. For instance we need to ask does the chalk and talk (Instructivist) philosophy toady provide graduates sufficient skills needed to perform well in changing environments. This paper investigates the application problem based learning methodology in engineering design.

2. PROBLEM BASED LEARNING RATIONALE

PBL is a teaching strategy that leads students to learn to learn and encourages students to develop critical thinking and problem solving skills that they can carry for life. [12] PBL is the search for solutions to life’s messy problems. It was developed by McMaster University Canada in medical and health sciences by the end of the 1960’s [13]. Problem-based learning (PBL) is an emerging teaching approach which has taken its prominence in tertiary education in recent years[14]. [15] PBL crosses a broad spectrum of instructional patterns, from total teacher control to more emphasis on self directed student inquiry. Patterns of power and control of decision making are affected by what [16] calls “reculturing”. It is a shift from the traditional didactic teaching where the core knowledge discovery process lies almost entirely in the hands of the learner rather than the teacher. [17] articulated what has become one of the most widely used definitions of PBL. He termed it “authentic PBL” and argued that it has four key characteristics:

1. **Problem-based.** It begins with the presentation of a real life (authentic) problem stated as it might be encountered by practitioners.
2. **Problem-solving.** It supports the application of problem-solving skills required in “practice.” The role of the instructor is to facilitate the application and development of effective problem-solving processes.
3. **Student-centred.** Students assume responsibility for their own learning and faculty act as facilitators. Instructors must avoid making students dependent on them for what they should learn and know.
4. **Self-directed learning.** It develops research skills. Students need to learn how to get information when it is needed and will be current, as this is an essential skill for professional performance.
5. **Reflection.** This should take place following the completion of problem work, preferably through group discussion, and is meant to enhance transfer of learning to new problems.

Applying PBL methodology in engineering design requires first clarifying what is meant by terms such as problem, whilst there are unintended consequences of using the term “problem” which may unnecessarily restrict the investigation or carry negative connotations, I personally would prefer to use the term “project”. Traditionally engineering design was effective in transmitting theoretical knowledge and skills to students, but it was seldom that undergraduate student were exposed multidimensional interdisciplinary problems which were similar to what’s likely they would encounter in real world. Knowledge of appropriate theoretical concepts does not ensure that students can solve real industrial problems [18]. [19] Pointed out the difficulty their students had in solving real problems, despite having knowledge of appropriate theoretical concepts. [20] Highlights the importance of developing inquiry skills, which includes critical questioning, finding relevant evidence, examining arguments and weighing alternatives.

In PBL the teacher becomes the facilitator to provide resources and guidance to students as they develop content knowledge and problem solving skills. TABLE 5 is a summary of comparison between traditional and problem-based learning environments. [21] have stated that there are three roles for PBL. The first is the acquisition of factual knowledge, the second is the mastery of general principles or concepts that can be transferred to solve similar problems, and third, the acquisition of prior examples that can be used in future problem solving situations of a similar nature. Learning styles are preferred ways of organizing what we see, remember and think about. Perhaps the best known dichotomy is between the convergent and divergent thinkers. Convergent thinking is associated with classroom learning. Divergent thinking which is linked to creativity is not encouraged in the classroom since divergers like to imagine and generate ideas [22].

Two elements contribute to one’s learning approach: motive and strategy. Motive denotes why one learns, while strategy refers to how one learns [23], [24] outlined how to make the best and improve use of one's learning style,

- **Pragmatist:** Relevant and practical, Try things out with support from an expert, Given immediate opportunities to implement what learnt
- **Problem solving:** Activists, New experiences, ‘Have a go’, Team work
- **Reflector:** Thinking things through, Observation, Paired discussions, Opportunity to review and reflect
Finally problem based learning in engineering design course pedagogy is made up of four components as illustrated in FIGURE 1, further more we will investigate PBL in engineering design from these four different lens.

3. REFLECTIVE PRACTICE

The concept of reflective practice is one that has roots in the work of [25]-[26]. Dewey proposed a theory of reflective thinking where he sought to “present his theory with increased definitiveness and clarify therefore making it more accessible for classroom teacher” [27]. Dewey’s approach to reflective practice has come to be characterised by three learner attitudes; open mindedness, responsibility and wholeheartedness [28]. [29] Identified two types of reflection: reflection-in-action and reflection-on-action. Reflection-in-action occurs when the person reflects on behaviour as it happens, so as to optimise his or her immediately following actions. Reflection-on-action is reflection after the event, allowing the person to review, describe, analyse and evaluate the situation, so as to gain insights for improved practice in the future. [30] portray the professional as a problem finder as much as problem solver. The concept of reflection and the psychological processes by which reflection is carried out are fundamental problems in activity theory [31]-[32]. Reflection is defined as a specific interaction between objects and phenomena that constitutes reflected objects within a dedicated medium of reflection. The most complicated type of reflection is psychological reflection [33]. [34] write the plethora of material associated with reflective practice has resulted in a diversity of labels, terms such as problem based learning, situation learning, experiential learning, action learning, critical reflection, critical pedagogy, narrative enquiry, reflection in action, despite the differences in nomenclature these forms of reflective practice indicate an epistemology of practice which places technical problem solving within a broader context of reflective inquiry. Through integrating theory and practice, [35] indicates how a variation on PBL also referred to as situation based learning can be used to help students reflect critically upon issues of practice.

4. CONSTRUCTIVIST LEARNING

Pedagogy can be defined as the art and science of teaching FIGURE 2 represents the pedagogical environment dimension as having two ends, instructivist and constructivist [36]. Where instructivist theory aligns with the classical instructional methods include lectures, demonstrations, writing term papers, preparing lab reports, and taking written examinations. [37] Presents the theories constructive alignment and phenomenological. There are two parts to constructive alignment: Students construct meaning from what they do to learn, the teacher aligns the planned learning activities with the learning outcomes.

Students engaged in engineering design by and large are interpreting, analysing, discovering, evaluating, acting, and problem solving. Hence the basis of engineering design consistent with constructivist learning, where knowledge is constructed by the learners as they are actively problem solving in a real world context, compared with hypothetical scenarios in traditional instruction, TABLE 6 [40] presents a comparison of design convergence.
perspectives. In [41] conceptions of learning, social-cognitive and social-constructivist perspectives, highlight the central importance of student participation in social interaction. A constructivist view of knowledge, “is particularly compatible with the notion of self-direction, since it emphasizes the combined characteristics of active inquiry, independence, and individuality in a learning task” [42] placed self-direction within a framework of four distinct yet related dimensions:

- a personal attribute,
- a self-management skill,
- a manner of organizing learning in a formal setting, and
- a manner of pursuing learning in non-institutional, natural settings.

<table>
<thead>
<tr>
<th>Strategies used more in PBL than lectures</th>
<th>Strategies used more in lectures than PBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using library resources</td>
<td>Using material from class sessions and objectives</td>
</tr>
<tr>
<td>Using general reference texts</td>
<td>Using recommended texts, basic science texts</td>
</tr>
<tr>
<td>Preparing for class sessions</td>
<td>Reading assigned material is useful</td>
</tr>
<tr>
<td>Participating in class</td>
<td>Taking notes in class sessions</td>
</tr>
<tr>
<td>When working in groups each person looks up one topic and then explains to others</td>
<td>Regular review of class notes</td>
</tr>
<tr>
<td></td>
<td>Using objectives, class notes and provided notes to decide what is important</td>
</tr>
<tr>
<td></td>
<td>Writing review notes in own words</td>
</tr>
</tbody>
</table>

TABLE 1: learning strategies differences between lectures and PBL contexts [43]

5. COLLABORATIVE AND COOPERATIVE LEARNING

[44] distinguished between co-operative and collaborative learning, both are social, group-based approaches. Co-operative learning focuses on the product, relating more to foundational knowledge, and can be seen as teacher-oriented whereas collaborative learning focuses on the process, sees knowledge as authenticated by the learning community and is learner-centred. According to [45] collaborative learning sharing of authority and acceptance of responsibility consensus building through cooperation deals with individual group members' abilities and contributions, in contrast to competition. Cooperative learning is defined by a set of processes which help people interact together in order to accomplish a specific goal or develop an end product which is usually content specific. [46] Myers identifies a middle way, called the ‘transaction’ approach, where we recognize the existence of the curriculum, but expect students and teachers to engage in a dialogue with it. [47] Identified the promotion of cross-cultural relations as one of the benefits of co-operative learning. Assessed tasks tend to be more structured than totally learner-managed ones and may inhibit the development of a learning community but we should seek to achieve ‘facilitative’ rather than constraining structure [48].

6. SELF LEARNING

According to Candy (1991) the learning cycle starts through a sequence:
- discrepancy, discomfort, challenge & conflict
- Identify problem/s
- Explore causes
- Research and analyze
- Develop solutions & implement
- Re-orientate & reform

Self-directed learning (SDL) is defined in very diverse ways within the adult and workplace education and vocational training literature. Some definitions associate self-directed learning with tightly circumscribed activities, like programmed learning. Others are much more open-ended, emphasizing autonomous or independent learning on virtually any topic by almost any means [49]. Conceptual framework of the early literature on self-direction [50]-[54] asserts orientation of self-directed learning in which the learner plans and initiates the learning process. "self-directed learning describes a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes". Self-directed learning with a person's ability to:
- decide what knowledge and skills to learn;
- diagnose his/her learning needs realistically, with help from teachers and/or peers;
• translate her/his learning needs into learning objectives in a form that makes it possible for the accomplishments to be assessed;
• relate to his/her teachers as facilitator% helpers, or consultants and to take the initiative in making use of their resources;
• relate to her/his peers collaboratively, to see them as resources for learning;
• identify human and material resources appropriate to different kinds of learning objectives;
• select effective strategies skilfully and with initiative;
• gain knowledge or skill from the resources utilised;
• evaluate his/her work and get feedback from others about progress;
• detect and cope with personal blocks to learning;
• Renew motivation for learning when motivation lags.

7. DISCUSSION

One of the paramount problems of learners in the discovery learning process is the regulation of their learning behaviour. Obviously, in self-directed learning environments the demand on regulative capacities of learners is larger than it is in traditional lectures. Planning and monitoring are central [55]. Whilst students learn in different ways each has a preferred style. [56]-[57] engineering design through PBL provides exclusive learning activities to the student’s inclination. Undergraduate students have the responsibility for their own learning, this is more so highlighted in problem-based learning curriculum where the onus is on the student to identify what they need to learn and what resources they are going to use to accomplish that learning.

Furthermore [58] provided the general philosophy of good practice in undergraduate education summarised by the seven principles, encourage contact between students and faculty, develop reciprocity and cooperation among students, encourages active learning, give prompt feedback, emphasizes time on task, communicates high expectations, and respects diverse talents and ways of learning. While each practice can stand alone on its own, when all are present their effects multiply in cooperation providing a commanding competence in education: activity, expectations, cooperation, interaction, diversity, and responsibility.

One of the primary learning outcomes of engineering design courses is to incorporate a major design experience into the undergraduate curriculum to reflect design projects in industry as illustrated in TABLE 2. In design projects students are actively involved working cooperatively together to help each other learn [59], furthermore they have clear goals, criteria to self pace, measure and tell them when the goals have been achieved [60]-[61] prompt feedback about their performance also nourish this category.

routinely I role play with the engineering students; approaching design projects as play-acting, I present myself as a client (mere customer), the assumption is that “I only understand things in layman’s term”, the scenario is “I have hired you (students) to do the design occupation, with that comes moral support and motivation from myself as well offering the students with self belief i.e. it is explained to the students that you are worthy experts/engineers. Hence as a lecturer role playing the “facilitator” also participating in the project on a student only request, is a basis to enhance problem solving skills, [62] found, it empowered the students to have some role in the peer and self assessment, by providing a supportive work atmosphere that expects success. This is usually done in parallel to the facilitators support, I usually approach it allowing students to scaffold using a mix of metacognitive strategies for example in a typical engineering design session I would include; face-to-face small group interaction; mind mapping reviewing information why and what are we designing; brainstorm using illustration and drawing, encouraging peer-group conversation to generate questions; evaluating action, and ideas for journal keeping reflection.

Hence up on the students presuming the role of an engineer, as a client I am at liberty to ask that they explain to me why things are being done, part of the role play is to learn and use the experience “We learn by conceiving and transforming our experiences” [63]. I also used to learn the engineers (students) preferred names for communicate. More importantly I took a personal notice in their extracurricular interests i.e. favourite football team, cricket leagues, squash player, hockey competition etc.. this view is in contrast to a formal student teacher relationship; one where you communicate (directly or indirectly) to the students that my role is to "weed you out," "cover the course material," "satisfy tough standards," "do my thing without getting personally involved with you the students," or "do my thing because the real reason I'm here is to do research."[64].

Another good strategy to foster problem solving and inquiry in design projects are derived from the [65] the first is KWHLAQ as illustrated in TABLE 3; I encourage the students to use these questions to determine the direction of the inquiry.

This strategy derived from K-W-L [66] a pre-reading strategy designed to engage students in thinking prior knowledge and purposes for reading. The second strategy derives from O-T-Q as illustrated in TABLE 4.
Reanalysis applied back to the design problem; where students apply through interactive discussions what they have learned to provide a deeper understanding of the problem and generating hypotheses of the final analysis of what was learned from the problem adding what concepts and principles which were used. This can be achieved through reflective journal where the students expand on there understandings of the mechanism used.

In addition the student a proficient skills to self and peer asses. [67] highlight a series of rules for success, develop new personal development approach to learning, use case study material drawn from real life, reinforce the material with input from professional, ensure the student realisation that there is no one right answer. [68] emphasised the value of projects in integrating course work and providing the opportunity to experience the total design process; through design to manufacture, they highlight the open ended nature of the project for which there is no one right solution.

The opportunity to obtain “design” experience, this means that the student goes through the complete design process, from drawing up their own program to arranging formal engagements (deliverables). To Learn how to avoid common pitfalls early in the design process the students assume responsibility for defining core interaction, people, and resources related to the design process. The workshops allowed students the opportunity to work in close contact with one another, Table 7, explains how collective experience was acquired and used in the design process through the mechanism listed.

<table>
<thead>
<tr>
<th>K</th>
<th>What do we know about pump selection?</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>What do we need to find out about; flow rate, total head, friction, fluid viscosity, temperature, PH, temperature, RPM, pump performance, energy balance, Bernoulli’s equation, suction size, discharge size, failures causes (vibration)?</td>
</tr>
<tr>
<td>H</td>
<td>How will we go about sizing a pump? Manufacturer’s catalogue, pump curves, rules of thumb, [69]-[71] industry standards IChemE, AIChE, How will we go about finding out? Use reference: [72]-[75]</td>
</tr>
<tr>
<td>L</td>
<td>What do we expect to learn? Pump selection, (centrifugal, positive displacement, Reciprocating, diaphragm), pipe sizing, Best efficiency point (BEP),</td>
</tr>
<tr>
<td>A</td>
<td>How will we apply what we have learned to our next projects? Individual responses</td>
</tr>
<tr>
<td>Q</td>
<td>What new questions do we have following our inquiry? Individual responses</td>
</tr>
<tr>
<td>O</td>
<td>Observe objectively We apply an approach to design that's focused on the total student experience; our goal is to simplify.</td>
</tr>
<tr>
<td>T</td>
<td>Think reflectively To reflect the importance of this experience and to provide the students with as much supervised design time as possible.</td>
</tr>
<tr>
<td>Q</td>
<td>Question frequently The process for which the students have the opportunity to question as often as they wish without fear of retribution or inadequacy.</td>
</tr>
</tbody>
</table>

**TABLE 7: Sizing a pump through PBL**

**8. A CRITICAL STANCE OF PBL**

PBL required the engineering students (learner) adopt a change in mindset from teacher-dependence to self-reliance. Whilst I support PBL philosophy, as a lecturer I occasionally observe PBL’s short comings and glitches, for instance independent and team learning are two key characteristics of PBL with self-reflection as an essential component in the learning process [76]. Although students are typically ingrained in their role as content receivers, as a lecturer I had often found myself increasing my own workload during PBL sessions in the following order; provide course content and more real examples, encourage engineering students to articulate the skill of reflective writing, and finally conducting the classroom as a facilitator. However my role is further diversified with other facets i.e. attending to at-risk students.

A major source of conflict identified during this PBL course was the “student not pulling in their own weight in PBL” Whilst a plethora of terms exists across the world for defining such students, the most common student slang I have recorded were; loafer, freeloader, sponger, stowaway. this contributes to conflict within teamwork in PBL, hence as a lecture my role was to conflict resolve aggrieved team members concerns which needs to be
attend to along with the issue of assessment of team assignments in PBL, as for assessment in PBL this topic falls outside the scope of this article however as PBL lecturer I also attempt to echo the engineering industry standard in the assessment strategy, for example; students are marked for not turning up to meetings, not doing their share of the written work, one or more members of their teams are not pulling their weight and that the collaborative nature of the unit has failed.

[77] Identified several behaviours that significantly predicted student learning, such as exchanging explanations and that student behaviour largely mirrored the discourse modelled by and the expectations communicated by teachers. in my view the inadequacy of PBL are that sometimes it is far more challenging then a instructivist teaching for instance establishing the social interaction, which happens to be one of the key ingredients of success hence dependent students tend to require more help, similarly a creative self reliant student often leaves me with a sense of guilt afterwards, for requiring minimal effort, hence wondering whether I ethically earned my pay. This confirmed by [78]-[83] understanding of the most frequent issues regarding PBL process that are raised as arguments against PBL are the dominant student, individual quietness and absenteeism or lateness and the greatest hindrance to learning are the dominant student, a disorganised / haphazard tutorial reasoning process and a superficial study of the problem.

9. CONCLUSION

The pedagogical environment in many engineering schools still remains predominantly instructivist in that, regardless of the discipline, where as in a decentralized era, an age of which knowledge is available to anyone, anywhere, at anytime professional life merges work and learning. Classical instructional methods views students as relatively passive recipients, professors teach and students learn. Engineering design through PBL provides Intellectual Maturity by allowing students to become Independent Learners, not only acquiring knowledge about what they know but also making them aware what they do not know hence keeping their expectations real and protecting them from what they do not know. It is fair to say that in terms of establishing a pedagogical equilibrium environment it is essential in PBL as it is a highly social experiences, I suggest that managerial/administration authorities at departmental level acknowledge the teaching load, schedule, class size, setting and delivery format for teaching staff members as PBL workload is deceiving in the first few years.

REFERENCES


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Appendix

<table>
<thead>
<tr>
<th>STAGE 1 Competency Standards For Professional Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE1</td>
</tr>
<tr>
<td>PE1.3</td>
</tr>
<tr>
<td>a. Ability to develop and construct mathematical, physical and conceptual models of situations, systems and devices, ability to utilise such models for purposes of analysis and design, and understanding of their applicability and shortcomings</td>
</tr>
<tr>
<td>PE2</td>
</tr>
<tr>
<td>PE2.2</td>
</tr>
<tr>
<td>PE2.3</td>
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<tr>
<td>PE2.5</td>
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<tr>
<td>PE2.6</td>
</tr>
<tr>
<td>PE3</td>
</tr>
<tr>
<td>PE3.1</td>
</tr>
</tbody>
</table>

TABLE 2: Australian engineering competency standards (Draft 5 February 2004) [84]

| K | What do we know about the subject? |
| W | What do we want/need to find out about it? |
| H | How will we go about finding out? |
| L | What do we expect to learn? What have we learned? |
| A | How will we apply what we have learned to other subjects? To our personal lives? To our next projects? |
| Q | What new questions do we have following our inquiry? |

TABLE 3: KWHLAQ inquiry

| O | Observe objectively |
| T | Think reflectively |
| Q | Question frequently |

TABLE 4: O-T-Q inquiry

<table>
<thead>
<tr>
<th>Traditional Classroom</th>
<th>PBL Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor assumes role of expert or formal authority.</td>
<td>Faculty member is a facilitator, guide, co-learner, mentor, coach.</td>
</tr>
<tr>
<td>Faculty members tend to work independently.</td>
<td>Faculty members work in teams together and with others from outside the discipline.</td>
</tr>
<tr>
<td>Faculty structure is supportive and flexible. Faculty members are involved in changing the instructional culture through the development of assessment tools that is congruent with PBL principles, including peer review.</td>
<td></td>
</tr>
<tr>
<td>Faculty members transmit information to learners.</td>
<td>Students take responsibility for learning, creating partnerships with teachers.</td>
</tr>
<tr>
<td>Faculty members organize course content into lectures based on discipline content.</td>
<td>Faculty members develop learning scenarios designed to empower students to seek information and to integrate what they find. Student motivation is enhanced through providing scenarios from real life, and thereby activating prior knowledge.</td>
</tr>
</tbody>
</table>
Students are viewed as passive recipients of information. Faculty members support students, encouraging initiative, guiding learning to enable students to transfer knowledge.

Students work mostly independently and often in isolation. Students interact with faculty and peers, thus facilitating the provision of immediate feedback and leading to remediation and improvement.

Students absorb, transcribe, memorize, and repeat information to accomplish content-specific tasks such as tests, exams, and quiz. Faculty members design course materials based on case scenarios, thus creating flexible learning environments for students.

Learning is individualistic and competitive. Students experience learning in a collaborative and supportive environment.

Students look for the “right answer” in order to succeed in an exam-driven context. Faculty members discourage one “right answer”, assisting students to frame questions, formulate learning issues, and explore alternatives.

Performance is measured on content-specific tasks. Students identify, analyze, and resolve learning issues using knowledge from previous experiences and learning, not relying solely on recall.

Grading is summative and the instructor is the only evaluator. Students evaluate their own contributions as well as those of other group members.

Lectures are based on one-way communication with information being conveyed to a student group. Students work in groups of varying sizes to approach the required learning task. Students acquire and apply knowledge in a variety of contexts. Students discover resources with faculty guiding them to the best information. Students seek useful and relevant knowledge to be able to apply into the future.

**TABLE 5: Comparison of Traditional and Problem-Based Learning Environments (Baptiste, 2003)**

<table>
<thead>
<tr>
<th>Constructivist</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge</strong></td>
<td></td>
</tr>
<tr>
<td>Constructed, emergent, situated in action or experience, distributed</td>
<td>Transmitted, external to knower, objective, stable, fixed, decontextualized</td>
</tr>
<tr>
<td><strong>Reality</strong></td>
<td></td>
</tr>
<tr>
<td>Product of mind</td>
<td>External to the knower</td>
</tr>
<tr>
<td><strong>Meaning</strong></td>
<td></td>
</tr>
<tr>
<td>Reflects perceptions and understanding of experiences</td>
<td>Reflects external world</td>
</tr>
<tr>
<td><strong>Symbols</strong></td>
<td></td>
</tr>
<tr>
<td>Tools for constructing reality</td>
<td>Represents world</td>
</tr>
<tr>
<td><strong>Learning</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge construction, interpreting world, constructing meaning, ill-structured, authentic-experiential, articulation-reflection, process-oriented</td>
<td>Knowledge transmission, reflecting what teacher knows, well-structured, abstract-symbolic, encoding-retention-retrieval, product-oriented</td>
</tr>
<tr>
<td><strong>Instruction</strong></td>
<td></td>
</tr>
<tr>
<td>Reflecting multiple perspectives, increasing complexity, diversity, bottom-up, inductive, apprenticeship, modeling, coaching, exploration, learner-generated</td>
<td>Simplify knowledge, abstract rules, basics first, top-down, deductive, application of symbols (rules, principles), lecturing, tutoring, instructor derived and controlled, individual, competitive</td>
</tr>
</tbody>
</table>

**TABLE 6: [40]**