Exploring the essence of productive pedagogy in Fluid Mechanics and Material and process curricula for second year Engineering

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Abstract

A Curriculum development in the fluid mechanics and material and processes subjects for foundation levels for the engineering students at university level has been assessed against the requirements of engineering education productive pedagogy in the new era. Four corners are essential for productive pedagogy namely Intellectual quality, Connectedness, Supportive learning environment and Recognition of difference. These are checked against the contents during the developments of curricula of the two subjects to comply with the outcomes which match the international standards.

The Teaching and learning styles can be enhanced when predominantly considering student based learning strategies. Case studies development and structure are encouraged to be considered in teaching material and process subjects. Employing problem based and project based styles of learning will lead to good practice, and ideas for optimum designer and consultant in materials and processes starting from engineering student level through productive engineering education.

Computer simulations are discussed and recommended as they have impact on the understanding of fluid mechanics and Material and processes by engineering students. Student difficulties with fluid mechanics and material and processes concepts can be dissolved through collegial support when they discussing a real life project they might be involved with in industry. The industry requires self directed engineers with minimum supervision and able to search and find solutions of the problems bearing in mind that not every thing available in the lectures and the textbooks. Therefore an engineer should be able to gain knowledge and also be a researcher. Intellectual quality and connectedness have to be taken further in laboratory classes and require not to be imparted from the theory classes.

The ideas of virtual fluid mechanics and materials and processes laboratory has been developed and initially will be tried in fluid mechanics subject for second year engineering students where four groups of students are far away from the central laboratory.

The curricula development reflect the challenges for a graduate engineer of professional design, project management, communication, industrial relations, application of technology and specific knowledge in Fluid mechanics and material and processes areas. This would add new excitement and immediate future in the ever-changing world of engineering. Considering the productive pedagogy in engineering education will support that teaching and learning are enjoyable arts when considering the great changes in teaching and research of the disciplines. This paper discusses how we can make our young engineers to be professional designers and future consultants for the two subjects through a productive pedagogy environment in engineering education.

KEYWORDS: Fluid mechanics, Material and process, teaching, engineering, laboratory, Project-based learning; Virtual laboratory, Engineering education
1. Introduction

Universities are increasingly viewed by students as well as by policy-makers and others as repositories of special expertise in improving the lifelong education by preparing their students for enhancing productive pedagogy. Four corners are essential for productive pedagogy namely Intellectual quality, Connectedness, Supportive learning environment and Recognition of difference. Teaching practice in Fluid Mechanics and Material and Process is no longer consisting of lectures and textbooks. Teaching Fluid Mechanics and Material and Process today possess deep background knowledge and are used to high standards of professional presentation which hold students’ interest. With changes in technology while surrounded with environmental uncertainty, it will be possible that a different concept of ‘Student Support” will emerge. The proposed profiles and practices will implement concepts and strategies which aim to prepare the students for lifelong learning.

2. Literature review

Four corner of Productive Pedagogy Framework [1][2][3]:

**Intellectual Quality (IQ):**

IQ indicators are the descriptors of the distinctive characteristics of authentic intellectual work as high order thinking, deep knowledge, deep understanding, substantive conversation, knowledge as problematic and metalanguage.

**Higher-order thinking** requires students to manipulate information and ideas in ways that transform their meaning and implications. This transformation occurs when students combine facts and ideas in order to synthesise, generalise, explain, hypothesise or arrive at some conclusion or interpretation. It is the training required of the engineering students to be suitable for working in various occupations and participating in practical real life problems and be able to face the challenge of applying basic skills and knowledge to complex problems of the real world.

**Knowledge is deep** when it concerns the central ideas of a topic or discipline, which are judged to be crucial to it. Deep knowledge involves establishing relatively complex connections to those central concepts.

Students develop **deep understanding** when they grasp the relatively complex relationships between the central concepts of a topic or discipline. Instead of being able to recite only fragmented pieces of information, they understand the topic in a relatively systematic, integrated or holistic way.

In classes with **substantive conversation** there is considerable interaction among students, and between the lecturer and students, about the ideas of a substantive topic; the interactions are reciprocal, and promote shared understanding.

**Presenting knowledge as problematic** involves an understanding of knowledge not as a fixed body of information, but rather as being constructed, and hence subject to political, social and cultural influences and implications.

**High-metalanguage** incorporates frequent discussion about talk and writing, about how written and spoken texts work, about specific technical vocabulary and words, about how sentences work or don’t work (syntax/grammar), about meaning structures and text structures (semantics/genre), and about how discourses and ideologies work in speech and writing.

**Connectedness**

Connectedness is characterised by knowledge integration, background knowledge, connectedness to the world and problem-based curriculum

**Knowledge integration**: Topics or problems which either require knowledge from multiple areas, or which have no clear subject areas basis in the first place are indicators of curricula which integrate the subject knowledge.

**Background knowledge**: High-connection occurs where topics provide students with opportunities to make connections between their linguistic, cultural, world knowledge and experience and the topics, skills and competencies at hand. Background knowledge may include community knowledge, local knowledge, personal experience, media and popular culture sources.
**Connectedness to the world:** Connectedness describes the extent to which the topic has value and meaning beyond the instructional context, making a connection to the larger social context within which students live beyond the classroom.

**Problem-based curriculum:** A problem-based curriculum is identified by topics in which students are presented with a specific practical, real, or hypothetical problem (or set of problems) to solve. Problems are defined as having no specified correct solution, requiring knowledge construction on the part of the students, and requiring sustained attention beyond a single lesson.

**Supportive learning environment**

Issues of classroom environment have been of concern to a very wide variety of educators and educational researchers. It is clear that students require a supportive environment if they are to achieve what teachers ask of them.

Supportive learning environment consists of student direction, social support, academic engagement, self-regulation and explicit quality performance criteria.

**Student direction** means that students influence the specific activities or tasks they will do in a lesson, or how they will undertake them. Such activities are likely to be student-centered ones such as group work, or individual research or investigative projects.

**Social support** is present in classes where the lecturer supports students by conveying high expectations for them all. These expectations include the following: (a) that it is necessary to take risks and try hard to master challenging academic work; (b) that all members of the team can learn important knowledge and skills; and (c) that a climate of mutual respect among all members of the team contributes to achievement by all. Mutual respect means that students with less skill or proficiency in a subject are treated in ways that continue to encourage them and make their presence valued. If disagreement or conflict develops in the learning environment the lecturer helps students resolve it in a constructive way for all concerned.

**Academic engagement** enhanced when the students are attentive and do the assigned work. They show enthusiasm for their work by raising questions, contributing to group activities and helping peers. Almost all students are deeply involved, almost all of the time, in pursuing the substance of the lesson.

**Explicit quality performance criteria** are frequent, detailed and specific statements about what the students are to do and to achieve. This may involve overall statements regarding tasks or assignments, or about performance at different stages in a lesson.

There may, on the other hand, be an absence of written or spoken reference to requirements, benchmarks, or levels of acceptable performance expected of students. In this situation the performance criteria are implicit. This may be a deliberate strategy for students to discover or construct their own outcomes, rather than indicating neglect.

Lectures who exert high implicit control rarely have to make explicit statements to discipline students (e.g. 'You're not being good today', or 'Tut your pens away'), or to regulate students' movements and dispositions (e.g. 'Sit down', 'Stop talking', 'Eyes this way' or 'Pay attention').

**Recognition of difference**

Recognition of difference is perhaps the most theoretically and practically significant dimension for explaining how to systematically improve the achievement of students from scholastically disadvantaged sociocultural backgrounds. Recognition of difference consists of cultural knowledge, inclusivity, narrative, group identity and active citizenship.

**Cultural identity** is represented in such things as beliefs, languages, practices and ways of knowing. Cultures are valued when there is explicit appreciation of these characteristics, and within the curriculum this requires that a range of cultures are acknowledged and given status. Cultural groups are distinguished by social characteristics such as gender, ethnicity, race, religion, economic status or age. Valuing those means legitimating these cultures for all students, through the inclusion, recognition and transmission of cultural knowledge.

**Cultural diversity** is devalued when curriculum knowledge is constructed and framed within a single set of cultural definitions, symbols, values, views and qualities, thus attributing some higher status to this one culture.

**Inclusivity** in classroom practices intentionally does acknowledge, support and incorporate the diversity of students' diverse backgrounds, experiences and abilities.

**Narrative** consists of a linked sequence of events. The use of narrative in lessons involves an emphasis, both in teaching and in student responses, on structures and forms. This may include the use of personal stories, biographies, historical accounts, and literary and cultural texts.

**Group identity** creates a supportive environment where difference is viewed positively and group identities are valued. Within the group of students there is a need to have a strong sense of community.
Active citizenship involves acknowledging that in a democratic society all individuals and groups have rights and responsibilities. They have the right to engage in the creation and re-creation of that democratic society, and to participate in all of the democratic practices and institutions within that society. They have the responsibility to ensure that no groups or individuals are excluded from these practices and institutions. In the classroom, the principle of active citizenship is followed when the lecturer explains these rights and responsibilities and ensures that they are adhered to, both within and outside the college.

Course learning outcomes In Fluid Mechanics (as taught at Central Queensland University for second year engineering students):

On successful completion of this course, you should be able to:

1. Explain the fundamental properties of fluids and apply this knowledge to analyse fluid flow in pipes [1, 3, 4, 5]
2. Analyse fluid systems using the concept of a control volume combined with the conservation of mass and momentum equations [1,3, 4]
3. Analyse incompressible flows in pipe systems [1, 3, 4, 5]
4. Apply similitude and modeling principles and techniques to problems in fluid mechanics [1, 3, 4]
5. Prepare technical and laboratory reports based on thorough evaluation of data and associated uncertainties [2]
6. Use appropriate "engineering language" in context [2, 6]
7. Document the process of modeling and analysis and present the information in a professional manner [2, 9]
8. Communicate, work and learn, individually and in peer learning teams in a professional manner [2, 6, 9, 10]

The following are the abbreviated Program Graduate Attributes of the highest level program that the course is offered in. The above learning outcomes contribute to those Graduate Attributes as designated by [ ]:

Bachelor of Engineering Graduate Attributes:
1. Science and engineering
2. Communicate effectively
3. Technical competence
4. Problem solution
5. Systems approach
6. Function in teams
7. Social, cultural, global and environmental
8. Sustainable design and development
9. Professionalism and ethics
10. Lifelong learning

Course learning outcomes For Material and Process (as taught at Central Queensland University for second year engineering students):

On successful completion of this course, you should be able to:

1. Classify and interpretively compare commonly used engineering materials with reference to material properties and fabrication processes.
2. Discuss the processes used to modify properties of engineering materials.
3. Select engineering materials to suit design and manufacturing requirements with consideration of environmental and service conditions.
4. Analyse the failure of engineering materials during service or processing, explain mechanisms of failure and determine appropriate protection measures against materials failure.
5. Research information, solves problems, and work effectively as members of a team and as individuals to complete projects on time.
6. Demonstrate effective development and use of professional self and team management and communication skills in team interactions and project work and in the preparation technical reports, designs and presentations.

3. Methodologies used in course profile design

3.1 Two assessments in Fluid Mechanics are project based and aimed to prepare second year engineering students in Fluid Mechanics Engineering Design. Working in real life projects provide the mechanical engineering students with a realistic understanding of the design process. The course profile assessment with regard to the design project is written from the viewpoint that design is the central activity of the engineering profession, and it is more concerned with developing attitudes and approaches than in presenting design techniques and tools.
Case studies development and structure are encouraged to be considered in teaching material and process subjects and can be demonstrated in Mini Projects. Employing problem based and project based styles of learning will lead to good practice, and ideas for optimum designer and consultant in materials and processes starting from engineering student level through productive engineering education.

3.2 Laboratory Reports

Objectives

This assessment item relates to the course learning outcomes 1, 2, 3, 4, 5, 7, 8 and 9 as stated above.

Details: This assessment comprises:
1A - Formal Laboratory Report for some laboratory experiments which performed in groups, 1B - Design your own experiment which is performed individually, 1C - Video Lab questions which is performed individually and virtual lab questions which performed in groups

Materials and Process Case Studies (mini projects) which as Fluid Mechanics are project based and aimed to prepare second year engineering students in Material and Process Engineering Design. The discipline of Materials Science and Engineering is ideal for using case study teaching because of the wealth of practical, real life examples that can be used to contextualise the theoretical concepts. Educational research has shown case studies to be a useful teaching activity. Case studies are an interactive learning strategy, shifting the emphasis from teacher-centred to more student-centred activities.

Differences and similarities between project-based learning (similar in structure to case study learning) and problem-based learning.

<table>
<thead>
<tr>
<th>Project-based learning</th>
<th>Problem-based learning</th>
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<tbody>
<tr>
<td>Predominantly task orientated with activity often set by tutor</td>
<td>Problem usually provided by staff but what how they learn is defined by students</td>
</tr>
<tr>
<td>Tutor supervises</td>
<td>Tutor facilitates</td>
</tr>
<tr>
<td>Students are required to produce a solution or strategy to solve the problem</td>
<td>Solving the problem may be part of the process but the focus is on problem management, not on a clear and bounded solution</td>
</tr>
<tr>
<td>May include supporting lectures which equip students to undertake activity, otherwise students expected to draw upon knowledge from previous lectures</td>
<td>Lectures not usually used on the basis that students are expected to define the required knowledge needed to solve the problem</td>
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We have found the case-based approach useful to the discipline of Materials Engineering. This discipline involves both ‘content and concepts’ and students can be engaged in learning both through a balance of:

Traditional lectures: Content is transferred and concepts can be identified and discussed
Laboratory Activities: Concepts are explored and further content learnt
Small group Tutorials: Consolidation of learning and problems identified
Case Studies: Content put into context and concepts reviewed

4. Discussion

Methodological sophistication has to be developed or found at the undergraduate level [6]. Teaching engineering subjects require the students to prepare the students to have [7]: a love of learning; a sense of curiosity and question asking and a critical spirit. Also require comprehension-monitoring and self-evaluation; a sense of the interconnectedness of fields; an awareness of how knowledge is created in Fluid Mechanics and Material and Process and an understanding of the methodological and substantive limitations of that field. Information literacy [8][9] in the two subjects demand: knowledge of major current resources available in the field of Fluid Mechanics and Material and Process; ability to locate, evaluate, manage and use information in a range of contexts; ability to retrieve information using a variety of media; ability to decode information in a variety of forms: written, statistical, graphs, charts, diagrams and tables; and critical evaluation of information.

This necessitate the inclusion of the productive pedagogy corners which are discussed here and after.

Intellectual Quality:
Higher-order thinking is the training required of the engineering students to be suitable for working in various occupations and participating in practical real life problems and be able to face the challenge of applying basic skills and knowledge to complex problems of the real world.

We should be teaching students how to think. Instead, we are teaching them what to think. [4]

A person who thinks critically can ask appropriate questions, gather relevant information, efficiently and creatively sort through this information, reason logically from this information, and come to reliable and trustworthy conclusions about the world that enable one to live and act successfully in it.

Students in Fluid Mechanics and Material and processes subjects are no longer in a similar role when they are reciting previously acquired knowledge; i.e., responding to test-type questions that require recall of pre-specified knowledge. More complex activities are applied.

Knowledge is deep as the construction of knowledge in Fluid Mechanics and Material and processes subjects aimed to produce sustainable professional performances that have value beyond the engineering college. This is important in engineering as engineers have to apply their knowledge to different situations.

Students develop deep understanding as they can produce new knowledge by discovering relationships, solving problems, constructing explanations and drawing conclusions especially in the Project Based Learning applied in teaching Fluid Mechanics and Material and processes subjects.

Substantive conversation is clear as without such substantive conversation they could not produce quality team projects impeded in Fluid Mechanics and Material and processes subjects.

Presenting knowledge as problematic was clear in teaching Fluid Mechanics and Material and processes subjects when presenting the importance of the specific knowledge learned in the projects especially with the issues of shortage of skilled professional engineers in the areas of Fluid Mechanics and Material and processes in labour markets nationally and internationally.

High-metalanguage incorporates areas were included in teaching the young engineers the importance of contracts and agreements in Fluid Mechanics and Material and processes projects. Lecturers choose teaching moments within activities and projects to focus on the importance on particular words, sentences, text features, discourses and so on.

Intellectual Quality In general as in [4]:

Lectures: present this is such a way that students will be encouraged to think critically about it. This is accomplished during lecture by questioning the students in ways that require that they not only understand the material, but can analyze it and apply it to new situations.

2. Laboratories Students inevitably practice critical thinking during laboratories in engineering class, because they are learning the scientific method.

3. Homework Both traditional reading homework and special written problem sets or questions can be used to enhance critical thinking. Homework presents many opportunities to encourage critical thinking.

4. Quantitative Exercises like in projects mathematical calculations and quantitative word problems teach problem solving skills that can be used in everyday life. This obviously enhances critical thinking.

6. Exams can be devised which promote critical thinking rather than rote memorization. This is true for both essay question exams and multiple-choice exams.

Your mission, if you decide to accept it, is to use one or more of the following classroom strategies or techniques to teach critical thinking in one or more of the above to improve the intellectual quality for the students.

Connectedness

The four corners of Connectedness which are characterised by knowledge integration, background knowledge, connectedness to the world and problem-based curriculum are contained within projects based learning in Fluid Mechanics and Material and Process(PBL).

Supportive learning environment

Supportive learning environment consists of student direction, social support, academic engagement, self regulation and explicit quality performance criteria.

Student direction

In Fluid Mechanics and Material and processes, the lecturer makes initial selection of activity, but students exercise some control through a choice of alternative activities prescribed by the lecturer. Student direction does not exist when all activities for the lesson are explicitly designated by the lecturer for the students.

Social support is dominant through team work activities in lab group questions and in projects.

Academic engagement when the students are attentive and do the assigned work required in both subjects.

Explicit quality performance criteria are important to produce quality projects.

Recognition of difference
Recognition of difference consists of cultural knowledge, inclusivity, narrative, group identity and active citizenship which are recognized in lectures, tutorials, laboratory and projects.

Evidence of Productive Pedagogy in Teaching Fluid Mechanics and Material and Process (by quoting the methodologies used in course profile design)

A. It is clear that the activity 1C is consisting of two sub activities:
1. Individual Brainstorming assessment for the lab videos related questions in the textbook.

Assessment objectives: To gain higher order thinking, Deep understanding, Deep knowledge and knowledge as problematic.
2. Group assessment for lab problems (Virtual lab). Group of four or five students shared answers.

Assessment objectives: Encourage Substantive conversation, Metalanguage, Knowledge integration, problem based curriculum and Connectedness to the world.

B. Projects in Fluid Mechanics and Material and Process:

Project based learning will develop students’ learning experiences and the engineers key attributes through a team-based design approach utilising the elements of sustainability in the projects related to fluid mechanics and Material and Process. It is considered a magnificent learning for what can not be taught within the university boundary. The students will experience a productive pedagogy in Fluid mechanics and Material and Process through improved Intellectual quality, Connectedness to real world outside the college boundaries, supportive team learning environment and recognition of difference between the team members.

Reminder: Sustainability is meeting the needs of present and future generation through integration of environmental protection, social advancement and economic prosperity.

Steps in the design process for Fluid Mechanics projects:

Weeks 1 & 2: Problem definition and Project Scope using fundamentals of fluid mechanics learnt and researched inside the boundary and extension to the real world outside the boundaries.

Weeks 3 & 4: Sustainable Concept design stage: Formulate Solutions, Develop sustainable concept designs complying to the course learning outcomes 1, 2, 3, 7, 8 and 9 as stated in Part A of the course profile, Document Concept Design

Week 5: Assessment: Project Part A: Design delivery stage A: Presentation by the groups representatives from each campus + Progress report for the whole Project Part A identifying who does what in a hardcopy and a memory USB for subject assessment filing. The marking will be by the tutor of different Campus with a consultation with your tutor for the individual cooperation in a team work.

Weeks 6 & 7 and 8: Preliminary sustainable design stage: Develop sustainable Models & Specifications, Revise, Refine Critiques

Weeks 9 and 10 Detailed sustainable design: Implementation, Document sustainable design complying to the course learning outcomes 3, 4, 5, 7, 8 and 9 as stated in Part A of the course profile, Review and testing. It is required from every Campus to build a physical sustainable project prototype which will be displayed at Rockhampton campus and will be the nice memory of our young engineers when they pass by the university in future.

Week 11: Assessment: Project part B: prototype will be fixed at Rockhampton, presentation of the project and a poster, final detailed design report identifying who does what in a hardcopy and a memory USB for subject assessment filing. The marking will be by the tutor of different Campus with a consultation with your tutor for the individual cooperation in a team work.

Off-Campus Students: Assessments in projects will be a Research Project Part A and B by choosing one project of a list given to the students.

Design project in Fluid Mechanics covers the developing attitudes and approaches to Fluid Mechanics engineering design. Students will acquire the learning knowledge and research capability required for an engineer. They will learn: the engineering design process, problem definition and need identification, team behavior and tools. They will research and gather information. They will generate and select concepts for decision making and detail design. This will take them to enjoy modeling and simulation, of materials selection and design for real life manufacturing. To make the design robust and with high quality output they will study
risks, reliability, and safety. The study of cost evaluation and legal and ethical issues in engineering design will lead to economic decision making.

With changes in technology it will be possible that a different concept of 'Student Support' will emerge. For many students, increase in information technology may allow the creation of the 'virtual classroom and library.' The trend may be a move from direct human support through tutorials and lectures to indirect support through Computers and data bases. These issues best applicable in universities with multi-campuses when the students can not move to the campus where the Lecturer conducts his lecture or tutorial session. This case in teaching Fluid Mechanics and Material Process for second year engineering students who are located in multi-campuses and who study by external mode.

With regard to the first of these domains, this research suggests that an explicit concern with lifelong learning is often built into the curriculum when a professional association or accrediting authority (a) specifically mentions this in their charter; or (b) insists on evidence of its importance in the accreditation and approval of undergraduate awards for certification [5].

**Conclusion**

The continuing changes in technology mean that people must be able to learn not only from familiar forms such as lectures, discussion sessions and written materials but from less familiar modes including educational broadcasts, video and audio cassettes, interactive teleconferences, computers, and even 'virtual reality.' Accordingly graduates need to be prepared not only to learn about technology, but to learn from it. Teaching in Fluid Mechanics and Material and Process is well planned to incorporate such changes in technology.

Computer simulations should be taken further as recommended to have impact on the understanding of fluid mechanics and Material and processes by engineering students. Student difficulties with fluid mechanics and material and processes concepts can be dissolved through supportive learning environment with recognition of difference. The proposed course profiles are impeding Intellectual Quality and Connectedness to have effective productive pedagogy in laboratory classes as suggested by other field papers[1]. Virtual fluid mechanics and materials and processes laboratory are now added values for student centred learning using problem based learning approach. Since undergraduates commonly will find themselves in relatively influential positions in business, government, defence, politics, religion, finance, science, the arts and other fields of human endeavour, they will likewise find themselves able to exert an influence well beyond their local scene of the university boundaries when working in Fluid Mechanics and Material and Process fields. Accordingly, an understanding of global interconnectedness is important to the appropriate exercise of their roles and responsibilities. This would add new excitement and immediate future in the ever-changing world of engineering.

A recent study [10][11] identified 18 major differences or discontinuities between the university and the workplace as learning environments. Whereas university learning is generally curriculum-driven, competitive, theoretical, abstract, long-term, and generalised, Workplace learning tends to be more problem-based, collaborative, applied, immediate, and specialised. These differences have been cast into even sharper relief by the recent dramatic changes which have impacted, and continue to impact, on Australian workplaces. This concluded employing the four corner of productive pedagogy utilizing PBL as problem based learning and project based learning are imperative for student centred learning in Fluid Mechanics and Material and Process. The Project Based Learning in Fluid Mechanics and Material and Process convey the "flavor" of design, addressing both traditional engineering topics as well as real-world issues like creative thinking, synthesis of ideas, visualization, teamwork, sense of customer needs and product success factors, and the financial aspects of design alternatives, in a practical and motivating manner.

**Reference:**


