

VARIATIONS OF PROBLEM-CASE DESIGN IN PROBLEM-BASED LEARNING

Azila NMA¹, Tan CPL¹, Zubaidah HAR², Wan Ashri WD³, and Khairiyah Mohd Yusof⁴

Faculty of Medicine¹, Faculty of Dentistry², Faculty of Engineering³, University Malaya, Kuala Lumpur and Faculty of Chemical and Natural Resources Engineering⁴, Universiti Teknologi Malaysia, Johor Bahru.

ABSTRACT

This paper describes approaches utilized to monitor cases used in problem-based learning and how they affected student learning, with the objective of improving the quality of cases. Problems or contextual situations used as triggers to stimulate discussion amongst students affect the quality of the small group process and drive students' learning activities, which in turn modify students' educational achievements.

Evaluation of the quality of problems was carried out using two instruments filled by teachers facilitating the PBL student groups. The first instrument was a case feedback form which provided information on how the problems worked for the groups. The second instrument was a learning objectives registration form to record learning issues/objectives identified by students working on the problem. Some information on case quality was obtained via observations during workshops with teachers or students.

An inadequate problem is characterised by learning issues that do not coincide with the intended goals for the problem. This occurs when the problem designed is too complex or not well written. Introducing didactic questions that focused on content, at times, distracted the students from the main issue of the problem especially when the questions reflected an assessment. The situation was made worse when the students were assessed during the PBL tutorial, based on how they answer the given questions, during a presentation to the class. However, in conditions where several groups were facilitated simultaneously by one facilitator, placing some "trigger" questions was seen to be necessary to help provide some focus and cues to help the students solve the problem/case study.

Keywords: PBL, case-design, quality of cases, student learning approach

INTRODUCTION

Over the course of the 20th century the view of learning changed in ways that affected educational practice. The most dominant description of learning is that learning occurs through knowledge construction. By 1980s the view of the learner changed from that of a recipient of knowledge to that of a constructor of knowledge, an autonomous learner with meta-cognitive skills for controlling his or her cognitive process during learning (National Research Council 2001). Thus many teaching/learning approaches have evolved to enhance learning outcomes. These include problem-based learning, case-based learning, project-based learning and field placements. A common thread running through each of these approaches is that they are student-centred, with students taking greater responsibility for their learning.

Implementation of PBL can be looked upon at two different levels. The **Macro level of implementation** refers to the broader elements of PBL practice as an educational approach and philosophy while **Micro level** refers to the PBL practice in the classroom which focuses on the experiences of facilitator/tutor and students, often learning in groups. It is characterised by the use of problems as the learning stimulus or triggers, encouraging self-directed learning including other structured or unscheduled learning activities, followed by application of the learning as they revisit the problem. These triggers affect the quality of the small group process and drive

students' learning activities which in turn modify students' educational achievements (Schmidt and Moust 2000, Polanco *et al* 2001, Khairiyah and Mimi Haryani 2003). Thus problems are pivotal in problem-based learning. This places high demands on the quality and focus of the problems. A case should include enough intriguing decision points and provocative undercurrents to make a discussion group want to think and discuss about them. Although a case or problem usually describes some phenomena or events that can be observed in daily life, it can also consist of important theoretical or practical issues (Schmidt 1983, Moust *et al* 2001). A case provides a framework for discussion which allows students (a) to recall what they already know, which can be used for brainstorming and hypothesizing, (b) to quickly identify the limit of their knowledge, and (c) to formulate a useful/specific question(s) to that limit (Dolmans and Snellen-Balendong 2000).

A well constructed case or problem should and function as a “surrogate teacher”. Most cases are designed to allow progressive disclosure of information. The cues presented, the sequence of its presentation, key prompting questions (if any), related to each bite of information should automatically lead students to discover the major goal intended by the case writers. Cases could and should be “model” examples of common, real-life situations (Kaufmann 1985, Tan *et al*, 2001, Schmidt and Moust 2000, Hallinger 2002). Based on research on learning and cognition, Dolmans *et al* (1997) recommended seven principles for effective case design. The **first** principle is that the contents of the case should adapt well to students' prior knowledge and level of study, so that it will help them mobilise what they already know. The knowledge gap created by the case must be appropriate for the level of the course intended. Too large a knowledge gap may lead to frustration when the students work on the case. The **second** principle depicts that a case should contain several cues that stimulate students to elaborate, encouraging discussion and search for explanation. It should not contain too many cues or irrelevant cues as they cause distraction or even confusion. The **third** principle is that the case must be in context relevant or linked to the future profession otherwise it will not motivate the students to learn. The **fourth** principle is that the case should present relevant basic concepts in the context of a suitable problem to encourage integration of knowledge. The **fifth** principle states that the case should stimulate self-directed learning by encouraging students to generate their own learning issues and conduct search for information. The **sixth** principle states that a case should enhance students' interest in the subject matter, by sustaining discussion about possible solutions and facilitating students to explore alternatives. Finally the **seventh** principle is that a case should match one or more of the faculty's objectives. Different types of problems can be designed to fit the level of study and outcomes (Dolmans and Snellen-Balendong 2000).

While discussing a problem, a group of students undergoes a process which helps maximise discussion and learning. This process is called the “seven jump” (Schmidt 1983) as shown in Table 1. The goal of the process is to ensure that in the end the students have gained a better, deeper and more detailed understanding of the mechanisms or processes underlying the problem (Schmidt and Moust, 2000). In other schools or discipline these processes may be grouped together and referred to as “five jumps” or coined in other ways (Kaufmann 1985, Woods 1994 & 1996, Kelson 2001, Barrows 2001, Hallinger *et al* 2002).

The authors and other members of the Faculties of Medicine (since 1995), Dentistry (since 1998) and Engineering (since 2002), University of Malaya, and the Faculty of Chemical and Natural Resources Engineering (since 2003), Universiti Teknologi Malaysia at Skudai, had undergone various workshops and intensive short courses locally and abroad to learn and experience facilitation, case design and block construction for use in developing PBL. These individuals, with the help of their colleagues or committees design cases and blocks for use in their respective courses (Tan *et al* 2002, Khairiyah and Mimi Haryani 2003, Abdul-Kadir *et al* 2003). Case design workshops conducted by the authors, to train other teachers, used Maastricht University's (Dolmans *et al* 1997) recommended seven principles for effective case design as the main reference. Other approaches were also referred to. The latter approaches are similar in concept, which were modified to suit the discipline involved or intent or focus of the problem at various stages of their programme (Barrows 1980 and 1985, Kelson 2001, Kaufmann 1985, Woods 1994

and 1996, Gijseleers 1995, Schmidt and Moust 2000, Clarke *et al* 2001, Wee *et al* 2001). Participants of the workshops were encouraged to experiment as they designed and used their cases for the students in their courses.

Table 1. The seven jump, adapted from Schmidt 1983

1.	Clarify unfamiliar terminology and concepts in the problem
2.	Define the problem and list the phenomena to be explained
3.	Analyse the problem: “brainstorm” – try to produce as many different explanations for the phenomenon as possible. Use prior knowledge and common sense.
4.	Criticise the explanations proposed and try to produce a coherent description of the processes that may underlie the phenomena or events
5.	Formulate learning issues for self-directed learning (or in other words, identification of knowledge gap)
6.	Plan actions to fill the knowledge gap using literature, practical, fieldwork, experiments, or patient interaction. Time given for the self-directed information search varies from a few days to a week, based on the complexity or objectives of the problem.
7.	Share findings with the group members in the following meetings and try to integrate the knowledge acquired into a comprehensive explanation of the phenomena or events

This paper describes the salient features that have emerged from our experiences and observations, and the experience of others using problems to stimulate learning. It will focus on the classroom experience of PBL especially in the context of how the cases affect the learning focus of the students and the challenges of assisting students in their development of self-directed learning.

METHODOLOGY

A problem, written by teams of teachers, aims to guide students’ learning towards certain subject matter and develop professional skills and awareness. In the Medical and Dental Faculty, University of Malaya, the relevant problem was presented to a group of 8 to 12 students for discussion, facilitated by a teacher. Usually the students have to explain the phenomena, or events narrated, in terms of their underlying mechanisms, principles or processes. In engineering a case/problem was presented to a group of 4 to 5 students for discussion, within a larger group of 60 students, facilitated by a teacher. The problems were mostly related to problem solving in design or management, especially in the fourth year. For initial discussion of each of the case used no pre-tutorial preparation was required of the students. They encountered the cases for the 1st time only equipped with their prior knowledge which may have been acquired through formal education, mass media or personal experiences of a similar situation.

Collection of data on the quality of problems was carried out using two instruments, filled by teachers facilitating the various PBL student groups in the medical faculty. The first instrument was a case feedback form which provided information on how the problems worked for the groups. In this form teachers were asked to comment on (a) how the problem worked in the groups they facilitated, whether it led to appropriate learning and identification of learning issues, (b) whether it led to frustration and why, and (c) the good/weak points of the case. The second instrument was a learning objectives registration form, to be filled by facilitators, to record learning issues/objectives identified by students working on the problem. This list was then compared with the list of intended learning objectives designed for the case. Some information on case quality was also obtained via personal involvement as facilitators of PBL groups, by the authors, and observations during various workshops with teachers or students in the various disciplines.

CASE-BLOCK CONSTRUCTION AND ITS OUTCOMES

1. Examples of problems from the various disciplines and their outcomes

Included in the appendixes are samples of problems given to students in the various courses in the institution of the authors. In this paper, discussions of outcomes included feedback from other cases not mentioned here. **Case examples 1 and 2** (Appendix 1) were sample problems given to the first and second year medical students at the University of Malaya, respectively. **Case example 3** (Appendix 2) was one of the problems given to the first year dental students at the University of Malaya. **Case examples 4** (Appendix 3) **and 5** (Appendix 4) were sample problems given to the second year Chemical Engineering students at the University of Malaya and at the Universiti Teknologi Malaysia in Skudai, respectively. Case examples 1, 2 and 3 were case scenarios without any written questions given to direct or focus the students' learning other than the events described. For case examples 4 and 5, written questions or assignments were included with the scenarios or parts of the scenario to help direct the focus of learning in stages. The latter approach of case design was adopted to provide more guidance since in engineering a teacher facilitates 4 to 12 discussion groups (of 3-5 students) simultaneously.

Case example 1 (Encik Amir) depicts a patient requiring cardiac bypass surgery. It consisted of two triggers, given sequentially to the group of students during the 1st encounter. The second trigger is given to the students by the facilitator at an appropriate time after discussion of the 1st trigger. This case induced the students to learn about the anatomy and physiology of the heart, including its blood and nerve supply, lipoproteins, lipid profile and how changes in that profile are related to cardiovascular disease. Relevant issues discussed include atherogenesis, common lipid lowering drugs and their general mechanisms of action. Behavioural, social and population issues include diet and lifestyle in relation to ischaemic heart disease (IHD), incidence, contributory factors and impact of the illness on patient and family.

Case example 2 (Rina) depicts a scenario of a patient with septicemia. It consisted of two triggers, given sequentially to year 2 students during the 1st encounter early in the endocrine system. This scenario included issues pertaining to medical microbiological and pharmacological concepts befitting the second year curriculum. The learning issues raised by the students for this case included learning about the common causes of sore throat and the rationale of using antibiotic treatment; definition, causes and manifestation of hypersensitivity, types of allergic reactions (esp. with respect to penicillins), cardinal signs of acute inflammation, acute inflammatory response, choice of medication or management with adjunct therapy. Behavioural, population and social issues included reaction to a life-threatening situation, anxiety in a strange environment, frequency of drug-induced allergies, and the importance of educating the patient and parents on future allergic reaction to similar medication.

It is pertinent to note that for year one and year two problems, learning of concepts and scientific foundation of medicine is the focus of learning but they are placed in the context of patient care to improve motivation. The cases mentioned above could be modified for use with 3rd year medical students. Cases used for the clinical years (3rd year onwards) induces the students to postulate differential diagnosis and to a certain extent the choice of management of the patient. At this level the diagnosis or management would not be included. The investigative procedures and the results would be withheld by the facilitator until the students ask for it, with appropriate explanation why those investigations or results are required. At this stage the students are already interacting with patients daily to take case histories.

Case example 3 (Mr Teoh) describes a scenario of a patient with dental caries in the upper and lower posterior teeth (Rahim *et al* 2003). The scenario focuses on tooth morphology and carries. This problem was used in cariology module for the year 1 dental students. It consisted of two triggers. The second trigger was given, at an appropriate time, after discussion of the first trigger. This case induced the students to learn about the types of teeth present in the upper and lower

posterior jaw, the anatomical/morphological features of the posterior teeth and their function, the difference between the upper and lower posterior teeth and between the molars and premolars, dental notations, definition of dental caries and the relationship between tooth morphology and caries development. Behavioural, social and population issues included the significance of the occupation of a fisherman to the risk of getting dental caries, their level of oral health awareness and dentist-patient communication.

Case example 4 (Reactor catalyst) describes a case given to year 2 chemical engineering students. It was in a form of a dialogue by a production manager (Ir. Abdullah Hassan), to be discussed by the students. This was followed by some trigger questions/assignment given near the end of the tutorial class, which triggered more questions and identification of specific learning issues. The main learning objectives of this case are reflected in the prompts given although students may discuss other related issues. In general students learn about components of catalysts and their method of production, understand different concepts and their difference, draw graphs, derive equation and exposed to data analysis. A case scenario, as depicted, could be designed to be used over several formal PBL tutorials within two to three weeks, with increasing complexity. Questions or tasks given to students at the end of each tutorial session were used as a learning guide and/or focus, and function as a basis for group presentation and/or report.

Case example 5 (GULA-GULA Sugar Refinery) describes a scenario, given in parts over 3 weeks in a mass and energy balance course in chemical engineering, related to concentration of raw sugar solution in a sugar refinery. The interval between the 3 formal discussions of the parts was 1 week. The learning issues raised after **part 1** of the case were to learn about the purpose of an evaporator, to name the system of units used in engineering calculations e.g., unit for pressure, define state variables and the purpose of degree of freedom analysis. The learning issues raised after **part 2** of the case included the general principle of mass balance, definition and derivation of the ideal gas law equation and a process flow sheet, the difference between steady state and unsteady state balance, the purpose of a pump, how to size a pump and how a degree of freedom analysis can assist in the determination if the system is well defined. The tasks accomplished after **part 3** included the demonstration of knowledge of unit conversions, drawing a process flow sheet of the process, performing the degree of freedom analysis and mass balance calculations for systems without reaction on single and multiple units, and using the ideal gas law. The instructions or tasks given in this session provided guidance on the focus of discussion and presentation, by the students, to be assessed by the teacher.

2. Overall Impression from feedback on identification of learning issues

Data and information collected with the two instruments used with the medical cases indicated that the cases used so far stimulated activation of the students' prior knowledge and stimulated enquiry and learning processes. For most cases used the groups identify between 60-70 % of the expected learning objectives. At times some other additional relevant issues, although not intended as a major issue by the case-design committee, were raised triggered by minor events narrated in the case. This was an important finding as it showed that every event narrated in the cases, no matter how minor, would lead to identification of issues not intended by the case designer(s). Thus designing effective problem requires skill and not just an expertise on a subject matter, critical evaluation of the narration to match with the intended learning objectives and lastly vetting of cases by a case-vetting committee not involved with the writing of the particular case. A few cases that were noted to be "overloaded with details", even at the case-vetting level, the learning issues identified by the groups matched between 20 – 80% of the intended learning objectives. Analysis of feedback showed that the students were distracted by the details and focused of them instead of the big picture, especially in the first year. A pattern noted, of the wide gap of achievements, implied that groups with lower matching of learning objectives occurred when the teacher did not provide the guidance required in such a situation while groups that had appropriate guidance achieved a higher percentage matching. This was another

important finding, in that when cases written were inappropriately the teacher's role in facilitation become more critical in helping the students achieve the intended outcomes.

3. Overall Impression from feedback and observations on use of questions

Analysis of cases, used for the last few years, showed that when questions were included in the problems students became distracted from integrated holistic learning, that is, with the questions provided the students tended not to explore the issues from various aspects but tended to focus on the questions since they had the impression that these questions reflected on aspects that will be examined. The use of questions, if inappropriate, inhibited lateral thinking and development of creative ideas especially if they questions were too direct. For example in Case Example 4 (Reactor catalyst), although prompt 1 led the students to focus on learning about catalyst components and methods of producing catalyst it was done because the question was given. It hindered the students from learning how to formulate the question itself or the need to derive that from the case scenario. The students did not go through a process of "chaos" before reaching "cosmos" as mentioned by Silen (2001). Omitting the question would have forced the students to analyse, stimulate discussion and agree on the learning issues required to help them to eventually understand or solve the problem. Therefore, the students would not only learn factual content but the process of enquiry and identification of their knowledge own gap. Prompt 2 is less didactic as it involves a higher level of cognition in which the students have to first learn about physisorption and chemisorption before they could differentiate between the two. It also provided some focus especially if the coverage of the topic is too wide and limited time is provided.

From the examples of cases shown we can acknowledge that the both health science students (medical and dental) and the engineering students will be somewhat familiar with the context of real-world problems as they go through they course of study. However, the medical and dental students will have a greater exposure to the process, application of theoretical concepts, management and practicality involved with patient care in the later years since they have the opportunity to interact with patients at the teaching hospital. In contrast, the engineering students will only be exposed to theoretical concepts unless practical, field work or posting in the relevant industries are also organized. However adopting the PBL approach is still beneficial since starting the learning process with a problem has been reported to assist students develop learning capabilities rather than emphasizing memorization (Hendry *et al* 1999). Clarke *et al* (2001) compared the cognitive process associated with working through problems given in Medicine and in the Computer Programming course. In medicine the usual objective is that the students develop the same diagnosis (convergent) based on evidence, with allowable variability (divergence) in the patient management plan based on patient or clients' requirements. In computer programming the students, after discussing the concepts involved, postulate many potential solutions to parts of a problem. The design process involves examining these alternative solutions and converge to one best suited to the client's needs. Students usually apply proven design strategies to efficiently choose a solution. Use of problems as triggers to motivate student learning has shown that it helps in improving learning attitudes towards an otherwise difficult course and eventually improve the students' performance (Polanco *et al* 2001, Khairiyah and Mimi Haryani 2003).

However, in the engineering courses, where the limitation of having one roaming tutor with several groups, sequential questions may help provide the much needed guide since the tutor were less able to follow the train of thoughts within each group during the session. Having group presentations helped provide information on the level of content attained, or more importantly level of cognition, to the teacher. With medical and dental courses each group was facilitated by one teacher throughout the two to three hour sessions. By following the group discussion closely the teacher could gauge the depth and breadth of knowledge engaged. Group presentations were then deemed unnecessary although it is still employed in dental faculty for the purpose of partial assessment. Thus it showed that case design variations are necessary to ensure appropriate learning based on the requirements of each discipline and resources available (Schmidt and

Moust 2000, Clarke *et al* 2001, Wee *et al* 2001, Farah Nini 2004, Azli NA 2004, Khairiyah *et al* 2004).

CONCLUSION

Monitoring of how students worked on problems is very important to ensure continual improvement of their quality and also as a feedback on student learning. An inadequate problem is characterised by learning issues that do not coincide with the goals previously identified for the problem. Principles for effective case design based on our experience include that:

- (1) **The problems must be designed with appropriate knowledge gap befitting of various levels of the undergraduate course.** Problems with appropriate knowledge gap clearly provides better motivation while complex “overloaded problems” causes distraction from the main issues of the case or even cause frustration. When cases were simple and transparent as to what was expected they discouraged discussion and de-motivated learning, in general
- (2) **The events in the scenario must be well written and not contained too many distracters.** This could also lead to frustration or superficial learning if inadequate time is given for brainstorming and the learning activities.
- (3) **Prompting questions can be included within the the scenario but they must be broad and more task-oriented.** Inclusion of didactic questions that focus on content distracted the students from the main issue of the problem especially when the questions reflect an assessment. The situation is made worse when the students are assessed during the PBL tutorial based on how they answer the questions given during their presentation to the class.
- (4) **Questions should only be included if deemed to be really necessary.** Inclusion of too many questions tended to reduce the opportunity for students to develop their questioning skills for self-directed learning and also de-emphasise discussion. This behaviour was also noted when the authors had workshops in other discipline that included students working on problems.
- (5) **Cases should not be presented primarily to “cover” a body of information but to allow students to “uncover” information and concepts** through discussion and data gathering. Prompting questions, if included, should be worded with various intentions, such as to stimulate hypothesizing or to foster integration not to obtain specific facts.

These findings concurred with other studies done, which not only looked into the influence of problem on students’ achievement through the tutorial process but other factors that come into play (Gijseleers 1995, Schmidt and Moust 2000, Clarke *et al* 2001, Wee 2001, Tan *et al* 2001, 2002 and 2003, Azli NA 2004). Finally it is pertinent to note that PBL has been practised differently in different disciplines and institution (Albanese *et al* 1993, Maudsley 1999).

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Case example 1 (Encik Amir)***Trigger 1***

Encik Amir, a 62-year-old retired headmaster, came to University Malaya Medical Centre (UMMC) clinic with his daughter. For the past two months he had been experiencing mild chest pain with several episodes of tightness of the chest upon physical exertion, such as climbing up the stairs to his bedroom or playing with his grandchildren.

Trigger 2

Encik Amir has been a heavy smoker since the age of 20. He usually had *nasi lemak* or *roti canai* for breakfast. He had not exercised regularly since the age of 30, when he injured his knee. He had been on Simvastatin for the treatment of hypercholesterolemia for the past two years. His fasting lipid levels were as follows:

Lipids	Encik Amir's results	Normal range
Total cholesterol	6.3 (mmol/L)	3.6 – 5.2
HDL	0.80 (mmol/L)	1.10 – 2.20
LDL	4.67 (mmol/L)	1.68 – 4.53
Triglycerides	3.3 (mmol/L)	0.4 – 1.5

A twelve-lead resting electrocardiogram was recorded and found to be normal. However, a treadmill exercise test was found to be positive. He was then scheduled for an echocardiogram. The echocardiogram showed that the function of the left ventricle was poor. Blood analysis showed that the cardiac enzymes were normal.

A coronary angiogram was also performed and showed that Encik Amir had severe narrowing in his major arteries. Subsequently bypass surgery was scheduled.

Case example 2 (Rina)***Trigger 1***

Rina, a 10-year-old girl, was seen by a general practitioner (GP) for sore throat. She was prescribed oral ampicillin and paracetamol. An hour later, she developed facial puffiness, especially around the eyes and mouth. Her face was flushed. She soon developed difficulty in breathing and became frightened. Her family rushed her to the hospital emergency unit.

Trigger 2

Rina's mother informed the doctor at the emergency unit that Rina's symptoms developed 15 minutes after ingestion of the first dose of the medication.

On examination, her pulse rate was 140 bpm, blood pressure 80/50 mmHg and she was clammy. Treatment was promptly started, and she was then admitted for overnight observation.

When she recovered, the attending doctor gave Rina and her parents advice about using similar medication in the future, and told her to get a Medic Alert® bracelet.

Case example 3 (Mr Teoh)***Trigger 1***

Mr. Teoh, a 29-year old Chinese fisherman from Pantai Remis, came to see the dentist complaining of toothache and pain in the lower left jaw. He also complained of food getting stuck in the upper right back tooth.

Trigger 2

Upon examination, the dentist found a large occlusal caries extending to involve the mesio-buccal cusp of 36 and a carious lesion on the distal surface of 15.

Case example 4 (Reactor catalyst)***Trigger 1 (1st encounter)***

Ir. Abdullah Hassan said: “In two months time we are going to shut down our reactor to replace the catalyst. I would like to form a new task force to handle the operation. Today I would like to inform you that we will receive two more quotations of porous catalyst manufactured by two different companies. I would like this newly established task force to look into the specifications of these catalysts and report to the committee in a month time. You are part of the task force please advise the committee the specifications (typical properties) that need to be looked into and their significant. In relation to the above assignment the task force is also required to investigate the causes that lead to the deactivation of the catalyst”.

Prompt 1: Write a brief note on catalyst components and methods of producing catalyst.

Prompt 2: Differentiate between physisorption and chemisorption

Trigger 2 (2nd encounter)

Laboratory data of porosity results obtained for two of the catalysts is given to students, with prompting questions or instructions.

Prompt 3: Determine the surface area of both catalysts using BET and single point BET equations and comment the significant of the results. The adsorbate use in the test is Nitrogen. You need to derive the equations first and state the limitations of the equations.

Prompt 4: List and explain different forms of isotherms. Based on mechanism of adsorption relate the pore size and isotherm curve

Prompt 5: Using mercury-helium method, for sample 1, the following measurements are obtained for the amount of catalyst sample (100g) placed in the chamber. The volume of the helium displaced is 45 cm³ and the volume of mercury displaced is 83 cm³. Find the pore volume, density and porosity of the catalyst.

Always start by writing down the theory and derivation before answering the question.

Case example 5 (GULA-GULA Sugar Refinery)

Case – part 1 (first encounter)

The management of GULA-GULA Sugar Refinery just installed a new double effect evaporator unit to concentrate raw sugar solution from 5 weight % to 60 weight %. The first evaporator operates at 30 psia and 110 °C. The second evaporator operates at 101 kPa and 710 R. The concentrated sugar from the second evaporator is then crystallized to 5 weight % water at 101 kPa and 50 °C. The density of the 5% weight sugar is 1.2 g/cm³.

As a process engineer at you are assigned to calculate the production rate of sugar and size of a feed pump required for the evaporator, based on the situation given (by the 3rd week).

To find what is required, you must first visualise the process in the form of a process flow diagram.

Case – part 2 (given at the 2nd encounter a week later)

From last week's scenario, it indicated that the operating pressure is low and the process temperature is high. Thus **an ideal gas assumption** can be safely made for vapour coming out of both **evaporators**.

Notation:

To find the production rate and pump size requires you to solve not only a single unit but also **multiple unit mass balances**. You must ensure that the units used are consistent. Define your system boundary in order to ensure that the degree of freedom is met. Remember (from your fluids class) that pump sizing depends on the volumetric flow rate.

Case – part 3 (3rd encounter in the third week)

Students were asked to

- define mass fraction, mole fraction, weight, volume and mole percent, mass, volumetric and molar flow rate,
- explain how mass balance calculations on multiple units can be verified and the effect of pressure and temperature on liquids