# KEEPING THE PROMISE OF RIGOUR AND CONTENT IN PBL CURRICULUM DESIGN ISSUES IN THE ONE DAY ONE PROBLEM PEDAGOGY

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***Abstract***

*PBL promises deep learning because it attempts to situate learning in authentic contexts and learning is activity oriented. This paper argues that the design of PBL problems as fully fledged activity systems is dependent upon conceiving the interconnections between intra and interdisciplinary aspects of knowledge structures. As an activity system, every PBL problem comprises the knowledge structure (both as a body of content and as strategies for inquiry) within the framework of a given discipline. It is reasonable to assume that the first step in conceptualizing the activity system in a PBL problem is to explicate the intra disciplinary interconnections in a body of content. Deconstruction of content using a simple model is proposed as a way of achieving this end.*

***Keywords:*** *PBL curriculum design, knowledge structure, inquiry, activity system, ill structured problem, PBL problems*

## Introduction

The preference for learner-centred pedagogical approaches stems from one aim: it is to make student learning possible. (Ramsden, 1992) In recent years, higher education has begun to accommodate this aim as evidenced by the focus on the use of constructivist learning environments (Jonassen, 1999), open-ended learning environments (Land and Hannafin, 1996), microworlds and anchored instruction (Cognition and Technology Group, 1992), problem-based learning (Savery and Duffy, 1995) and goal-based scenarios (Schank and Cleary, 1995). Among these, the epistemic assumptions and pragmatic, design issues in problem-based learning are of interest to this discussion.

Problem-based learning is said to encourage and support deep learning strategies because students 'learn' through the activation of their prior knowledge. In order to achieve this end, PBL problems offer a learning space comprising the knowledge structures of a discipline and the strategies for inquiry. This is easier said than done because it is difficult to know what goes on while a student is learning. Epistemological traditions in psychology have used meta level monitoring of student work – retrospective interviews and think aloud protocols in particular being the most widely used. The typical pattern in think aloud protocols, though, produces plenty of talk while the students are figuring out how to go about the task but the point at which they discover an opening (something like 'Aha') is followed by total silence until the plan of action is completed or they get stuck again. (Laurillard, 2002)

A major challenge in PBL curriculum development is to design the 'learning space' in the form of ill structured problems. In practical terms the creation of an ill structured PBL problem involves the definition of learning issues anticipating a certain level of divergence and the setting of self corrective regulative mechanisms to ensure learning. The thesis of this paper is that careful analysis of subject matter content (as a body of knowledge) in terms of intra disciplinary and inter disciplinary connections can facilitate both the external representation of the curriculum (as knowledge structures) as well as the variable, internal representation of it by the learners (the inquiry process).

This paper makes the following arguments:

(i) Activity theory which has its roots in the classical German philosophy of Kant and Hegel provides a framework for the design of learning spaces in PBL problems
(ii) An expert can deconstruct the content he/she proposes to encapsulate in a PBL problem mapping the intra disciplinary and cross disciplinary connections (knowledge structures) and the inquiry process.
(iii) Granularity and combination, scope and sequence – the four key principles of object-based design can be used for deconstructing the content in PBL problems.

**Creating 'Learning Spaces': Epistemic Framework**
The classical German philosophy of Kant and Hegel emphasized both the historical development of ideas as well as the active, constructive role of people formulating ideas. This philosophy provided the foundation for the Soviet cultural historical psychology of Vygotsky and Leont'ev and Luria on which activity theory is based. Actvity theory negates the Cartesian divide between mind and body and adopts Marx's dialectical materialist view of activity and consciousness as dynamically interrelated. (Leont'ev, 1972) Both the theory of 'situated cognition' (Vygotsky, 1962) and activity theory posit that conscious learning emerges from performance and not as a precursor to it. This is an essential framework for designing PBL curricula because PBL is activity orientated. Further both learning and assessment of it are viewed within the context of the activity or performance (Venkatachary and Kluit, 2004), The assumptions behind activity theory which support the notion of contextualised performance are summarised as follows:

<u>Minds in context</u>
While traditional theories prescribe learning before action, activity theory believes a priori that the human mind emerges and exists as a special component of interactions with the environment; hence activity (sensory, mental and physical) is precursor to learning. Mind and body are interrelated so knowing can only be interpreted in the context of doing.

<u>Intentionality and object – orientation</u>
Since learning and doing are inseparable they are both initiated by an intention. Intentions are directed at objects of activity. Just as environmental cues provide affordances for perceptions, objects provide affordances for activity.

<u>Collaboration</u>
... "the individual's activity is a system of social relations." (Leont'ev, 1981). Activities are complex and interactive which necessitates collaborative effort.

**PBL Curriculum Design: Foreground and Background Issues**
PBL environments consist of several interdependent components – a 'learning space', the portrayal of the learning space (in the form of an ill structured problem statement which acts as the object of activity), information resources, cognitive tools, and conversation and collaboration tools. (Jonassen, 1999) Every PBL problem in this sense holds an activity system.

The problem statement captures the activity system and must engage the students. They may emerge from real world contexts. Engineers design bridges, circuit boards, airplanes; philosophers apply ethical principles of rendering judgment on ethical dilemmas.
The PBL problem is made up of three integrated, highly interrelated components:

- The context of the problem statement (as a portrayal of the activity system)
- The principle from the discipline/domain (which is the goal of the learning activity system)
- The interconnections within the discipline specific content (and the cross disciplinary linkages) as well as the strategies for inquiry

In dedicated PBL settings (such as the Republic Polytechnic, Singapore) the entire curricular content is designed as a series of ill structured PBL problems. The curriculum for programmes and modules then needs to be designed, articulated and transacted as a series of problems: it is important that the problems remain self-contained learning units on the one hand and consist of meaningful links within and across modules on the other. The first consideration is important because each problem is studied and solved within a specific span of time. The second consideration is significant because it is only through the understanding of the linkages that transfer of learning will take place.

**_One Day One Problem_ Approach at the Republic Polytechnic**
The implementation of PBL at the Republic Polytechnic, Singapore is characterised by division of a given curriculum (say, of a module) into 16 PBL problems. A module is transacted in a semester and a semester comprises 16 weeks of contact study time. In effect, students work in teams on a given PBL problem for the span of a whole day (8 hours approximately). Each PBL problem carries a set of learning outcomes, a context for learning activities and exploration (articulated in the problem statement) and scope of assessment. Each day is structured into three meetings with the facilitator and two segments of time when learning is self-directed: individual study, pair work or team work. In the first meeting, the students perceive and respond to the portrayal of the activity system – they respond to the problem statement as a way to identify their strategies for inquiry (within the scope of the problem. Usually they use a template with three questions: What they know', What they do not know' and 'What do they need to find out' in order to solve the problem. This template sets the tone of inquiry for the day – which may well be characterised as a series of pertinent questions and answers. In the second meeting, more discussions take place – with the facilitator's role focuses on listening and diagnostics. The students present and defend their solution in the third meeting. At the end of the day's work, a number of activities are carried out – a quiz, a Reflection Journal entry, self and peer evaluation. They receive a grade and diagnostic feedback on performance from the facilitator. This structure implies that a PBL problem encapsulates both the knowledge structure (connections within a discipline and across disciplines) and the strategies for inquiry.

**Representing Knowledge Structures**
Instructional designers have recognized the importance of analyzing subject matter content for the purpose of facilitating learning though appropriate selection, organization and sequence. A widely used set of categories was proposed by Bloom and his associates (Bloom et al 1956, Krathwohl et al, 1964). Gagne (1965,1985) proposed a taxonomy of learning objectives which rests on conditions for learning based upon information processing theory. Reigeluth, Merrill and Bunderson (1978) proposed that a prerequisite relationship among knowledge components represents only one type of knowledge structure. For them, knowledge components are facts, procedures (steps), concepts and principles. Merrill and his colleagues in the ID2 Research Group proposed a knowledge representation scheme consisting of these components arranged into knowledge objects (Jones, Li and Merrill, 1990; Merrill and ID2 Research Group, 1993, 1996; Merrill, 1998). They suggest that almost all cognitive subject matter content can be represented as four types of knowledge objects. Entities are objects or things. Actions are procedures that can be performed by

the learner on, to or with the entities. Processes are events that occur often as a result of some action. Properties are qualitative or quantitative descriptors for entities, actions or processes.

**Representing Knowledge Structures in PBL Problems**

As stated earlier, the learning space in a PBL problem encapsulates both the interrelationships evident in the content of a discipline as well as the strategies of inquiry which lead to the interpretation and understanding of the content on the one hand and which lead to the cross disciplinary linkages being made, on the other. This premise contradicts the rather narrow definition of knowledge structure cited earlier.

This paper argues the representation of knowledge structure in PBL problems involves the explication of three components:

(i) The context (problem trigger): information about a device, object, person, place, symbol and so on

(ii) Processes: A set of related events that occur either independent of the learner or as a consequence of the learner's actions

(iii) Activities: Sets of related tasks performed by the learner (asking questions, finding answers, reading, writing, experimentation, and so on)

(iv) Associations: The meaningful links between process, context and action

(v) Abstraction: The essence of a specific problem (in terms teaching-learning). It may be a principle, a process and so on. Abstraction pertains to the specific content domain/discipline.

These components need to be made clear specific and explicit terms before they can be integrated into the problem statement. The paper argues that a method of deconstruction can used to make explicit both the knowledge structures and the strategies for inquiry.

**Deconstruction as a Method for Designing PBL problems: Ensuring Granularity**

If a PBL problem were to hold an activity system (as discussed earlier in this paper) and if it were to encapsulate certain knowledge structure and strategies for inquiry, it is important that the scope of the problem is defined well. The issue of scope is related closely to the design consideration of granularity – for two reasons. One reason is that any activity system can work well and achieve the intended outcome if its definition is clear and manageable and the other reason happens to be the structured setting of one day one problem model (described elsewhere in this paper).

The method of deconstruction involves the articulation of the interconnections in the content of a discipline in explicit and step-by step manner. Figure 1 consists of a diagrammatic representation of the flow of content and inquiry in a PBL problem.

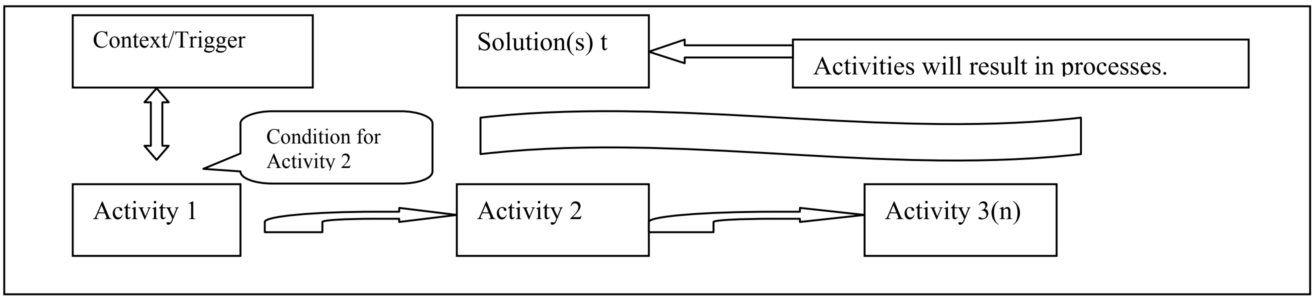


Figure 1: Learning Space in a PBL Problem

Figure 2 offers an illustration of how this may be done. The problem used as an example was run in Week 10 of Semester 2 and is from the module Programming Fundamentals (C106) for the Diploma Programme in Computing and Information Technology. All the labels are in bold while the analysis content is in oval shaped boxes.

Problem statement from C106: Programming Fundamentals; ‘Numeric Mastermind’

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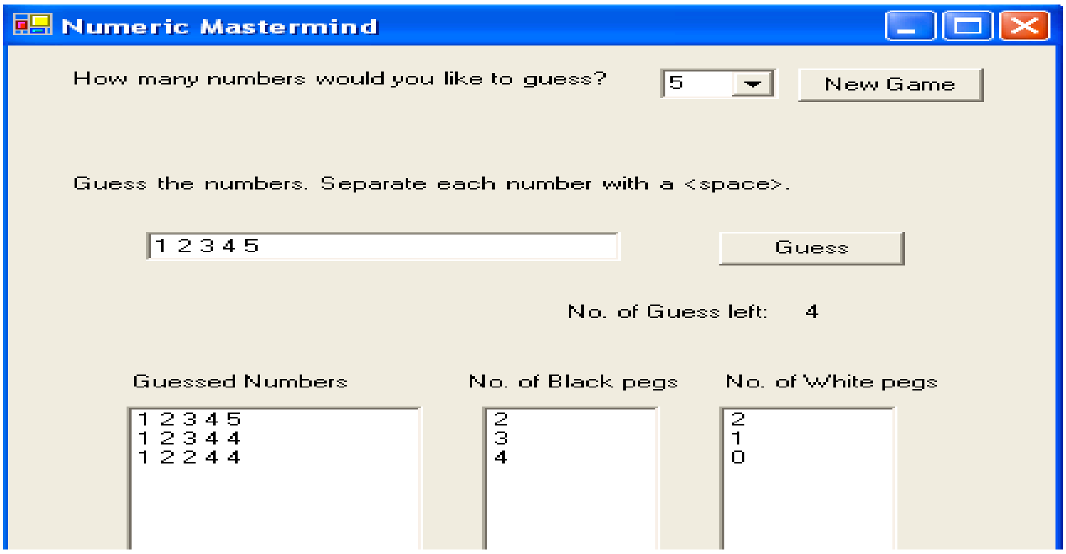
Develop a game that operates like the traditional mastermind. The player is required to guess numbers instead of colours. This game looks like this:




The game should function as follows:

1. The player first selects how many numbers to guess. The length of the number sequence can be 3, 4 or 5.

2. The application randomly generates the integers in the number sequence. Each integer is a value between 0 and 9. This sequence is unknown to the player at this time in time.

3. The player can try to guess the sequence by entering the numbers into the application. Each number must be separated with a <space>.

4. The application records the guessed sequence and allocates some pegs.

   - For each correct number in the correct position, the player is given 1 black peg
   - For each correct number in the wrong position, the player is given 1 white peg

***Example:***
*The player has selected to guess a 5-number sequence.*
*The random sequence generated is 1 2 2 3 4.*

*The player’s first guess is 1 2 3 4 5.*
*“1” and “2” are correct numbers in the correct positions, so two black pegs are given.*
*“3” and “4” are correct numbers in the wrong positions, so two white pegs are given.*
*“5” is not a correct number, so no pegs are given.*

*The player’s second guess is 1 2 3 4 4.*
*“1”, “2” and “4” are correct numbers in the correct positions, so three black pegs are given.*
*“3” is a correct number in the wrong position, so one white peg is given.*
*The repeated “4” is not considered to be a correct number, so no pegs are given.*

5. The application continues until the player has guessed the sequence correctly or if the player has made a total of 7 guesses. If he fails to guess the sequence within 7 chances, the application is ended and the answer is revealed.

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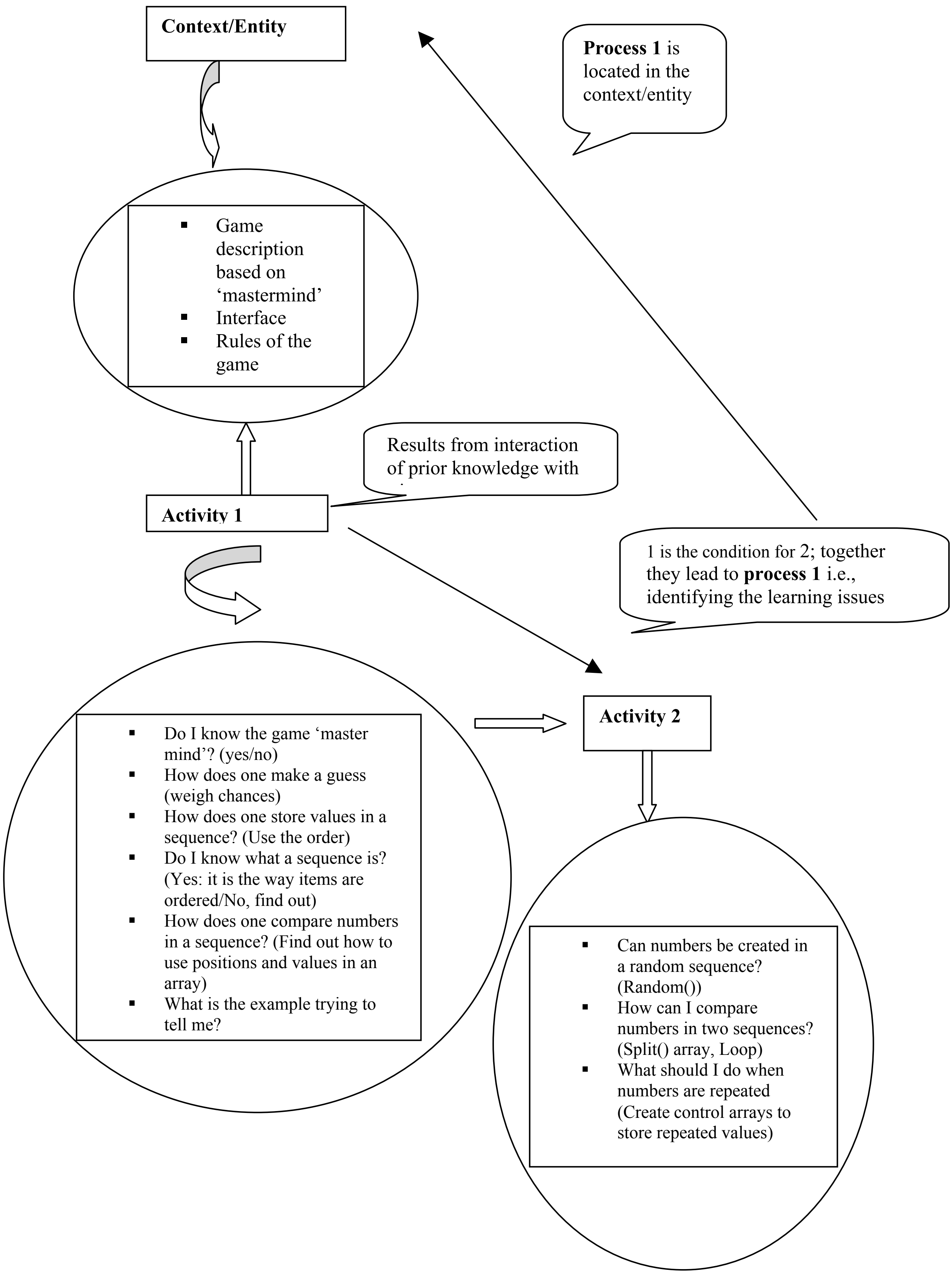

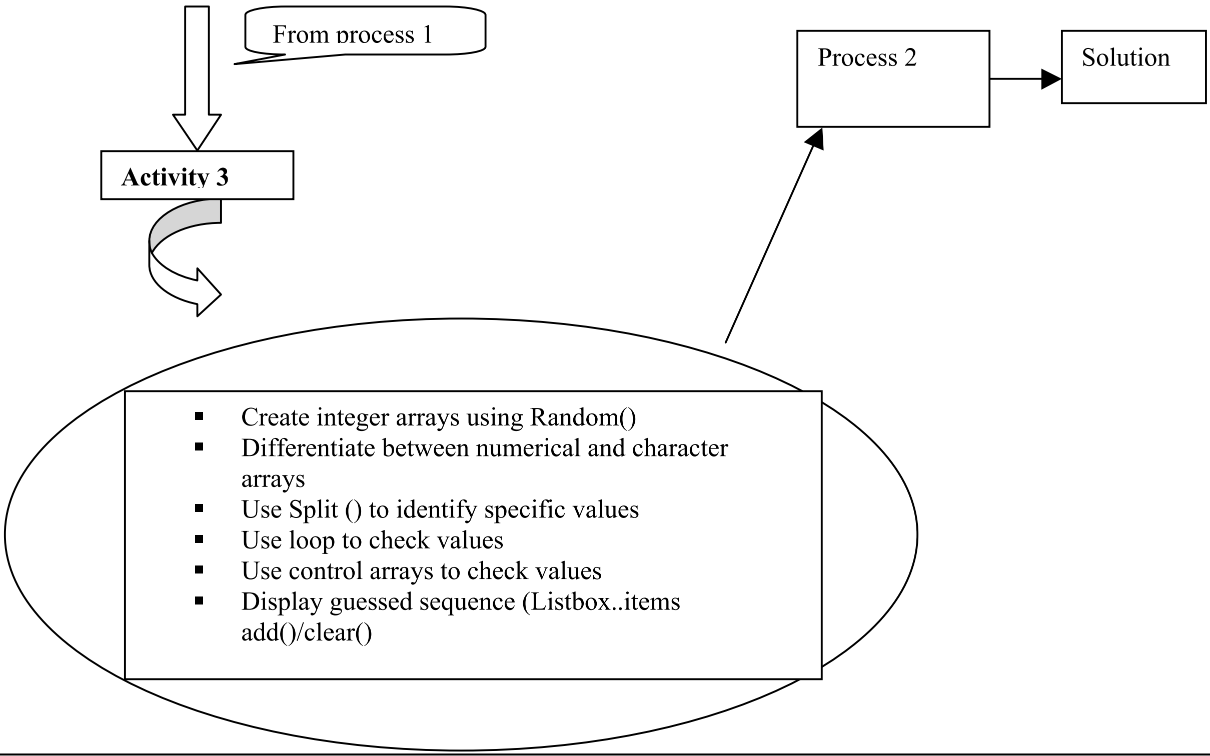


Figure 2: Representing Knowledge Structure in Discipline Specific Content

As a way of elaborating these frames of reference in the content, the key associations made (while working out this example are:

- The connection between the notion of randomness and guessing
- The notion of an array as a sequence of items
- The possible way(s) of generating sequences at random

As a result of these associations, the PBL problem in the example was abstracted to one key idea:

- The position (the ordering) of items dictates a sequence
- A sequence changes when the position of values is changed or when the values are changed.

Stating the interrelationships in the content of a discipline clarifies the logical structure of the activity system (to be contained in the PBL problem). Further it also offers insights into the choice of contexts/portrayals.

For example, the illustration of the rules of the game in this problem statement was critical in enabling the process of inquiry.

The design issues of granularity and scope manifest themselves when the knowledge structure in a PBL problem is made explicit in terms of the connections in the content.

**Sequence and Combination as Design Issues**

Any curriculum design effort must take the issue of sequence into account because inquiry as a process is progressive in nature. Questions and answers, the cultivation of attitudes or mindsets, and so on happen as successive events and this signifies understanding.

In the creation of PBL problems for the one day one problem pedagogy, the issue of sequence is addressed at two levels: the outcomes of the module as well as the statement of relationships between specific PBL problems. In line with the analysis of the illustration for the design consideration of granularity earlier, the relationships between the discipline specific content of two problems from the module on Computing Mathematics II (C102) offered towards the Diploma in Computing and Information Technology are analysed below.

| Time of study | Learning Space | Relationships indicating sequence | Learning Outcomes |
|---|---|---|---|
| Week1 | ▪ The notion of probability as the calculation of likelihood of an event happening<br>▪ The differentiation between theoretical probability and experimental probability | The calculation of the likelihood between two or more independent events is the one of the simplest conceptual manifestations of the notion of probability in mathematics.<br><br>The dimension of replacement of elements changes the nature and method of calculation. This is done in Week 2 | The ability to do calculations to demonstrate understanding of the differentiation between theoretical and experimental probability |
| Week 2 | ▪ The calculation of the likelihood of a particular choice (among options)<br>▪ Understanding how the configuration of options and choices change when the first choice is made (without replacement) | The dimension of replacement changes the number of available options and the likelihood of one of them being chosen.<br><br>Therefore, the calculation takes the branching of values (changes) and their dependence on the likelihood of a choice being made into account.<br><br>This concept is an extension of the learning space of week 1. | The ability to demonstrate through calculations that the likelihood of a choice is dependent on the configuration of options. |

Table 1: Illustration of 'Sequence and Combination' in Discipline Specific Content

The issue of sequence is particularly significant in view of the fact that a module is transacted through 16 successive weeks of problem solving.

**Discussion and Conclusions**

The main thesis of this paper focuses on the premise that knowledge structures in PBL environments include

- The interrelationships in a particular content domain or discipline
- The interrelationships across disciplines (as cross disciplinary linkages)
- The process of inquiry which is at once an articulation and a result of these intra and cross disciplinary linkages

It is the interplay between these three aspects which make the PBL problem into an activity system.

However as a design effort, these aspects of the PBL environment need to be conceived and articulated in a careful manner. The paper argues that making the intra disciplinary interrelationships in content is essential and probably the first step for the creation and articulation of the activity system. This reasoning is based upon the view that the perception and portrayal of intra disciplinary interrelationships will lead to a stronger and clearer statement of cross disciplinary linkages.

Further the abstraction of the fundamental principle (to be learnt) in every activity system is critical to the creation of PBL problems. This is dependent on the clarity with which an expert perceives the intra disciplinary relationships in content. Deconstruction of content is proposed as a way of achieving the desired level of clarity.

If we assume that every PBL problem is a self-contained learning unit, an activity system which encapsulates knowledge structures and the strategies for inquiry, then the unpacking and articulation of their component parts is a crucial and significant aspect of PBL curriculum development.

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