Seven principles of effective case design for a problem-based curriculum

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SUMMARY *Cases are the driving force behind students' independent study in problem-based learning. Evidently, the nature of student learning in problem-based learning is to a large extent dependent on the quality of cases presented to students. This implies that student learning can be improved by controlling the quality of cases. Several studies have been conducted to assess the effectiveness of cases. These studies provide us with evaluative tools, but not with principles for effective case design. More general research on learning and cognition has brought into reach some findings from which principles for effective case design can be deduced. In this article seven principles emerging from this research are outlined and for each of the principles an example is given of an effective or ineffective case.*

Introduction

Cases are a starting-point for students' learning activities in problem-based learning (PBL). A case usually consists of a description of some phenomena which require some kind of explanation. The task for the students is to explain the phenomena described in the case. While discussing these phenomena, some questions remain unanswered. These questions are subsequently defined as learning issues and are the driving force behind students' self-study (Schmidt, 1983a). The nature of student learning in PBL is to a large extent dependent on the quality of the cases presented to students. This notion was confirmed by Gijselaers & Schmidt (1990) and Schmidt *et al.* (1995). They developed a model characterizing important features of a problem-based curriculum and investigated causal relationships to assess the adequacy of the model. The results showed that the variability in functioning of small-group tutorials and time spent on individual study were, to a great extent, explained by the quality of cases used. An improvement in the quality of cases, all other things being equal, will result in improved group functioning, resulting in an increase in time spent on self-study (Gijselaers & Schmidt, 1990). These findings imply that the learning of students in PBL can be improved by means of controlling the quality of cases.

In this respect, it is surprising that little research has been done to investigate features underlying effective cases. Most studies investigating effective cases have focused on the relationship between student-generated learning issues and faculty objectives (Coulson & Osborne, 1984; Shahabudin, 1987; Dolmans *et al.*, 1993). In a more recent study, a protocol was developed to break down the content of a case into small units of information in order to measure the effectiveness of the input of a case (Kamin, 1995). Although these studies provide us with many useful tools to evaluate the effectiveness of cases, principles for effective case design cannot be deduced from these studies. Whether it is possible to design studies that will be helpful in generating principles for case design is open to discussion, because these studies are probably a fallacy.

Experienced faculty know some intuitive guidelines for designing effective cases that are only summarily documented (Majoor *et al.*, 1990). Although these experiences are worth dissemination, designing cases should no longer be exclusively centred on experience-based knowledge, but also on evidence-based knowledge. Such evidence can and probably should not be obtained from studies that are explicitly designed to deduce principles for effective case design. More general research on learning and cognition has brought into reach some findings that demonstrate why and how student learning can be facilitated. The intent of this article is to set out principles for effective case design from these findings. Seven principles are outlined, based on modern findings on the nature of learning and cognition. The seven principles are:

(1) The contents of a case should adapt well to students' prior knowledge.
(2) A case should contain several cues that stimulate students to elaborate.
(3) Preferably present a case in a context that is relevant to the future profession.
(4) Present relevant basic sciences concepts in the context of a clinical problem to encourage integration of knowledge.

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(5) A case should stimulate self-directed learning by encouraging students to generate learning issues and conduct literature searches.
(6) A case should enhance students' interest in the subject-matter, by sustaining discussion about possible solutions and facilitating students to explore alternatives.
(7) A case should match one or more of the faculty objectives.

These principles provide some help in designing effective cases in PBL. In this article the evidence underlying each principle is described briefly. In addition, each principle is outlined and an example of an effective or ineffective case is presented for each of the principles.

Prior knowledge

One of the pertinent findings of research on learning and cognition is that prior knowledge strongly influences the nature and the amount of new information that can be processed (Anderson, 1990). Based on their prior knowledge, learners actively construct explanatory models, which in turn facilitate the processing and comprehension of new information. Thus, preliminary discussion in the small group should help students mobilize whatever knowledge is already available (Schmidt *et al.*, 1989). This leads to the following principle:

> **Principle 1**: Ensure that the contents of a case adapt well to students' prior knowledge, because it will help the students mobilize what they already know about the contents of the case. Look into curricular materials students have been confronted with previously.
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> **Example**: A man, aged 70, visits his general practitioner because of fatigue. He has been feeling 'different' than usual for quite some time. His weight has increased considerably over the past few years. This often bothers him. A year ago, he started to fall and stumble regularly. Moreover, his vision has deteriorated in the past year; he sees everything through a haze. Maybe he needs stronger glasses.

The objectives for this case are to make a diagnosis and subsequently draw up an examination and treatment plan. The diagnosis is diabetes mellitus. It is evident that this case would *not* be effective in the first year of study, because students should during preliminary discussion in the tutorial group activate what they already know about metabolic processes, such as insulin formation.

Elaboration

New information is better understood and recalled if students are stimulated to elaborate on it (Anderson, 1990; Schmidt *et al.*, 1989). Elaboration can take several forms, such as discussion, answering questions, asking critical questions and giving explanations. These activities will increase the number of relations between concepts and the number of details in students' semantic networks and will lead to sophisticated knowledge structures. Elaboration will help students construct rich cognitive models, so that they have additional retrieval paths along which to recall the knowledge acquired (Anderson, 1990). This implies that a case should stimulate students to elaborate. This leads to the second principle:

> **Principle 2**: Ensure that a case contains several cues that stimulate discussion and encourage students to search for explanations. The case should, however, not contain so many cues that the task for the students consists of separating out relevant cues from non-relevant cues. Pointless cues will distract students.
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> **Example**: Susan feels her baby moving in her womb. Beside this new experience, a number of things have changed during the last six months. Her breasts have enlarged and have become more sensitive. Sometimes, she loses a few drops of milk. Furthermore, she has gained about six kilograms in weight and feels like a swollen balloon. Her husband complains of Susan eating too many sweets. Because Susan has gained weight, her clothes do not fit any more. Furthermore, she is experiencing some physical troubles. She has felt clumsy in the last few weeks because she breaks a lot of things. Needlework, one of her favorite hobbies, is very difficult for her. For a few weeks she has been unable to stand temperatures above 25 degrees Celsius. Her shoes do not fit any more and her rings pinch. Because of heartburn behind her breastbone and tingling fingers, she sleeps poorly at night. Despite all these inconveniences, she really enjoys her pregnancy, she feels a fulfilled woman, a feeling she has never had before.

This case was presented to students to study adaptation of the mother's circulatory system and metabolism during pregnancy and to study changes in a mother's body functions, behaviour and mood during pregnancy. Students confronted with this case will probably start listing the changes described in the case, such as enlargement of breasts, gain in body weight, tingling fingers, psychological changes, and subsequently will try to explain these phenomena. Thus, the cues presented in the case will elicit elaboration.

Relevant context

Research on human memory shows that information is better recalled if the context in which the information is applied closely resembles the context in which the information is learned (Brown *et al.*, 1989; Godden & Baddeley, 1975; Tulving & Thomson, 1973). Situated knowledge is assumed to be better accessible for later use, because the situational cues that activate the knowledge are stored within the same cognitive structures. This implies that students should be exposed to some professionally meaningful problems or situations that have a strong resemblance to the problems they will be confronted with in their future profession. This leads to the following principle:

> **Principle 3**: Preferably present a case in a con-

text that is relevant to the future profession, or at least show the linkage to the future profession.

Example: A 42-year-old man is brought to hospital by ambulance as an acute patient. The ambulance staff report that they picked the patient up at a bar called 'The Last Hope', where he had fainted after vomiting blood in the toilet. The emergency doctor examines the patient. The man is unshaven, smells of alcohol and is drowsy. His limbs are cachectic in contrast with his swollen abdomen. Before consulting the internist, the emergency doctor decides upon additional examination. While making a phone call to the internist, the accident department nurse reports that the patient is vomiting large amounts of blood again and that the blood tests show many abnormal values, including a Hb of 4 grams per decilitre mmol/l and a significantly increased ammonia level. The prothrombin time is 14 sec.

This case was presented to students to teach them to take rational decisions with respect to medical thinking and acting, based on their knowledge and understanding of the underlying pathophysiological processes related to abnormal blood loss. The situation described in this case represents a problem students might be confronted with in their future profession and gives rise to a discussion of several issues of medical thought and action, such as how urgent the situation is, what to do first, and so on.

Integration of knowledge

Several studies have shown that the integration of basic science knowledge and clinical knowledge results in better diagnostic performance by students (Hmelo, 1994; Schmidt *et al.*, 1996). If basic sciences concepts are learned in the context of a clinical problem within a clinical setting, these concepts will be better integrated. Problem-based curricula are also assumed to encourage the integration of biomedical knowledge and clinical knowledge (Barrows 1985; Norman & Schmidt, 1992). In a recently completed study conducted by Schmidt *et al.* (1996), students trained within the context of a PBL curriculum displayed better diagnostic performance than students trained within a conventional curriculum. The integration of basic and clinical sciences is assumed to cause this effect. This leads to the following principle:

Principle 4: Present relevant basic sciences concepts in the context of a clinical problem.

Example: A nineteen-year-old man, George, is helping his friend, Alice, to construct a bookshelf during the weekend. After Alice has laboriously removed a splinter from George's thumb, he decides to use gloves. Alice is not spared either. She cuts her forefinger with a knife. The heavily bleeding wound is washed under the tap and after the bleeding has stopped, the wound is covered with a plaster. Two hours later, she removes the plaster and observes that the skin surrounding the wound has become red. The wound itself is covered with a small scab and the borders surrounding the cut are swollen. Ten days later, the scab is released spontaneously and only a red stripe underneath her unimpaired skin is visible. George, however, has more trouble. On Tuesday morning he observes a red swelling near the edge of the nail of his right thumb which feels stiff. The skin around his thumb is tight and red and his whole thumb is throbbing. Moving his thumb is almost impossible and moving the wrist is also painful. On Thursday afternoon, George is feeling feverish and he decides to visit his general practitioner. The doctor observes a red stripe across the inside of his forearm. In addition, in both his elbow and his armpit the doctor feels swollen and painful glands. From the opening in the wound from which the splinter was removed, a small drop of pus is running slowly. This pus is sent to the laboratory. In addition, a blood sample is taken and sent to the laboratory. After a treatment with an antibiotic, George quickly feels better.

When being confronted with this case, students might wonder why George had such trouble, whereas Alice's wound initially looked worse but recovered without any further problems. While trying to explain this phenomenon students will discuss some basic sciences concepts, such as blood coagulation, natural healing process of a wound, infection and inflammation. Thus, students are confronted with basic sciences concepts in a case that is presented in the context of a clinical problem.

Self-directed learning

Modern theories in the science of learning and cognition emphasize the importance of active learning. Many investigations have indicated that competence is fostered not primarily by teaching to deliver knowledge or teacher-centred approaches, but through teaching to engender specific kinds of cognitive activity (Glaser, 1991). All too often, teacher-centred approaches force students to answer questions that they would never themselves have asked. By contrast, students should be actively engaged in acquiring knowledge and should themselves define to a large extent the content to be mastered. Curricula should prepare students to become independent, self-directed, lifelong learners. In PBL, students decide for themselves what is relevant for their learning, because they personally define the learning issues (Barrows & Tamblyn, 1980). Moreover, students conduct literature searches themselves and learn to find the necessary materials independently. As such, PBL promotes a learning style conducive to lifelong learning, as is indirectly evidenced in a study by Blumberg & Michael (1992). This leads to the following principle:

Principle 5: Ensure that a case encourages students to generate learning issues and conduct literature searches. This implies that a case should not be too structured. A case that contains explicit questions that need further explanation or a case containing references to literature providing solutions to the issues raised in the case will not prepare students to become more accomplished self-directed learners.

Example: A few days ago Sophie's child was born. The delivery took place without any complications. At home normal life has continued. Her husband has been working since yesterday. Sophie, however, sleeps badly and is tired all day. A few minutes walking hurts Sophie's legs. Furthermore, she is still bleeding. Sophie asks her obstetrician how recovery of the menstrual cycle takes place and when contraceptives are required.

This case is aimed at studying postnatal phenomena of the mother and the newborn child. The last sentence in the case presented above contains one explicit learning issue and does not stimulate students to define for themselves what is relevant both to learn and to generate other learning issues, such as the psychological condition of the mother and newborn child, breast feeding versus bottle feeding etc. Eliminating the last sentence of the case would improve its effectiveness.

Interest in the subject-matter

Intrinsic interest in learning will extend the time that is spent on self-study (Cooley & Leinhardt, 1980). In addition, time spent will positively influence students' performance (Schmidt, 1983b). Thus, learning should be made more intrinsically interesting. PBL is assumed to enhance students' intrinsic interest in the subject-matter. In an experiment, students discussed a case and tried to explain the phenomena in this case in terms of their underlying mechanisms. At the end of the discussion session, experimental subjects were more interested in attending a lecture on this issue than control subjects (Schmidt, 1983b). This leads to the following principle:

Principle 6: A case should sustain discussion about possible solutions and facilitate students to explore alternatives in order to enhance their interest in the subject-matter. This can be done by presenting phenomena in a case that need further explanation. In addition, gearing a case to the students' perception of their environment will also enhance their interest in the subject-matter.
Example: In the early morning Paul comes home drunk, after a night of heavy drinking. He tries to unlock the door, but the closer he brings the key to the lock, the more his hand shakes. Finally, he succeeds by facing the lock as straight as possible. Even then, it is difficult to turn the key. When he is finally inside, he feels the room reeling, even when he closes his eyes. His legs are wobbly. He tries to make a cup of tea, but after breaking lots of matches and burning his hand, he gives up.

The context in which this case is presented is geared to students' perception of their environment. Life as a student is often associated with a bustling night life, due to which students might be familiar with the situation described. This will probably motivate them to spend time on how control and regulation of movement take place via the central nervous system and what the influence is of drinking alcoholic beverages on the central nervous system.

Faculty objectives

That a case should match the objectives stated by the case writer is self-evident. If a case does not lead students to spend time on the intended faculty objectives, the intended learning outcomes are not accomplished, so that gaps in students' knowledge can exist. This implies that cases should direct students to confront one or more of the faculty's objectives. All too often, teachers design a case having in mind a particular situation that has attracted their attention, but do not ask themselves whether confronting students with the situation will result in achieving one of the faculty objectives specified for that particular course.

Principle 7: Work out what faculty objective(s) students will be confronted with while analysing and studying the case.
Example: Acetaminophen (paracetamol) is a valued pain-killer, which can be bought without prescription in a pharmacy and is used by millions of people. After taking a tablet, the analgetic effect usually starts within one hour and lasts four to five hours. Acetaminophen (paracetamol) is easily metabolized (half-life 1–3 hours) and normally has hardly any side-effects. There is, however, a snag. Acetaminophen has become one of the most popular suicide drugs in Great Britain. After intake of more than 20 tablets, a dosage of 10 g, in the first few hours nausea and vomiting often occur. After two days acute liver damage manifests itself, which may be accompanied by jaundice. Depending on the dosage and individual sensitivity, the liver damage can become irreversible and in the end lead to hepatic coma and death. Early detection of the symptoms of acetaminophen intoxication is of great importance, since the hepatotoxity can be opposed by means of the antidote N-Acetylcysteine. Adequate treatment with this drug can save a life.

This case was designed to stimulate students to study pharmacokinetics. Because the text pays considerable attention to the effects of an overdose of acetaminophen on the liver, students will probably focus on the side-effects of acetaminophen, instead of the dynamics of drug absorption and distribution and how acetaminophen is metabolized. Eliminating the effect of an overdose of acetaminophen on the liver and focusing the text on how acetaminophen is metabolized resulted in improvement of the case's effectiveness. Scrutinizing the learning issues generated by the students for this redesigned case indicated that considerably more learning issues were generated with reference to pharmacokinetics, as compared with the old case.

In this article seven principles of effective case design have been deduced from findings of research on learning and cognition. As a consequence, the design of cases should no longer be exclusively centred on experience-based knowledge, but can and should also be centred on evidence-based knowledge. Although the design of studies aimed at generating principles for case design is probably unsound, there is a need for further more general studies in the natural context of problem-based learning. These studies could for example focus on whether students actually construct new ideas while discussing a case or on how particular features of a case affect the discussion in the tutorial group and subsequent individual study.

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