

**Questioning to learn and learning to question: Structure and function of
PBL scenarios in environmental science education**

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Manuscript accepted for publication in Higher Education

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Abstract

In problem-based learning, scenarios relating to real life are used as a point of departure for the learning process. Even though the importance of suitable cases or scenarios to bring about a fruitful learning process is emphasised in the literature, few studies focus on how they actually function in the learning process. This study focuses on how the scenarios used in a ten-week introductory course of a new four-year, undergraduate programme in environmental science functioned in terms of the structure and content of the questions they evoked. Data were gathered through diary notes from nine groups of students, comprising 5-8 students per group. The data were subjected to a qualitative analysis aimed at describing the structure and content of the questions generated by the groups. Five different kinds of questions were identified and labelled; *A. Encyclopaedic*, *B. Meaning-oriented*, *C. Relational*, *D. Value-oriented* and *E. Solution-oriented*. All scenarios generated questions pertaining to all five categories in all groups, but the emphasis varied. The results are discussed in relation to the design of scenarios, and in relation to students' approaches to learning.

Key words: Problem based learning, scenarios, questions, questioning patterns, learning process, qualitative analysis

Introduction

One of the key features of problem-based learning is the use of scenarios relating to real life as a point of departure for the learning process. The design of these scenarios varies to a large extent and they are referred to in the literature as e.g. problems, cases, vignettes or, as here, scenarios. The intention is to get the students to associate the scenarios with real-life situations. The scenarios are considered to provide a meaningful context for the concepts and principles that relate to future professional work.

The learning process in problem based learning is considered to follow a sequence of interrelated steps. First, the scenario is presented to the students who then bring up their free associations in a brainstorm. The result of the brainstorm is arranged into a number of emerging themes and questions are posed in relation to each theme. The idea of the initial phase is to enable the students to clarify their preconceptions and prejudices in relation to a certain topic. The clarification is accomplished as they scrutinise and discuss their associations, ideas and themes that have been generated in the brainstorming process. The major goal of the described process is to facilitate and support the identification of learning needs. In other words, it is assumed that the students through this process learn how to identify their knowledge in relation to a discerned problem, to identify their learning needs and to identify how to best acquire the relevant knowledge.

The discussion in the literature on PBL appears a bit confusing, as the word 'problem' is used with multiple meanings. To begin with, in every day life, a 'problem' has negative connotations, pointing at something troublesome, that must be sorted out. In PBL, however, a 'problem' may be defined as "to be constituted by the questions, that can be asked about a situation or a concept, of which one or more are particularly relevant for one's education"

(Kjellgren et al. 1993, p.23). Another issue that contributes to the confusion is that 'problem' often is used interchangeably with the context or the scenario from which the problem is to be generated.

Standard texts on problem-based learning emphasise the importance of well-designed cases or scenarios in bringing about a fruitful learning process (Kjellgren, et al. 1993; Boud & Feletti, 1991). The intention is to engage the students in an active dialogue focusing on their own learning process and thereby bring about educative learning. According to Margetson (1997), educative learning is not only about gaining factual knowledge but also about learning the process, i.e. how questions are generated from a scenario and how content and process may interact. The educational intention of PBL seems, however, to be realised in different ways as educational practice (Abrandt Dahlgren, 2000). The role of scenarios in problem-based learning appears to serve different purposes in different academic and professional cultures, possibly depending on differences in perspectives on subject matter and learning.

Margetson (1998) outlines two variants of PBL which are generated from different perspectives of what counts as a problem and the role of the scenarios. In addition, he argues that the views of the structure of learning differ with regard to these two variants. He labels the variants the 'Convenient peg' and the 'Growing web' conception, respectively. The former is characterised by learning viewed as a two-stage process. The initial stage is the acquirement of a theoretical foundation of knowledge in what is referred to as 'basic sciences'. The second stage, in which the students are to 'apply' their basic science knowledge to a professional problem, appears later in the process. In this conception, the scenarios are regarded as small, delimited, single problems. Hence, they are obvious and non-problematic and serve the purpose of convenient pegs on which to "hang the coat of 'basic' science knowledge" (ibid., p. 196). According to Margetson, it is questionable whether the

'convenient peg' conception is consonant with the intentions of PBL. These intentions appear to be more truly met in the 'Growing web' conception which is characterised by the scenarios themselves being dependent on the context in which they appear and not necessarily comprising a given solution. Problem and context are regarded as an inseparable, inter-related whole. The learning process in becoming a professional is seen as a coherent whole from the beginning. Thus, information, concepts and reasoning, skills and attitudes are acquired in relation to each other in order to support each other and no division between the acquisition of basic science knowledge and its application is made.

What then, are the characteristics of a suitable scenario for problem-based learning, and what role does the scenario play in the learning process? Few researchers have focused on these issues but one example is Dolmans and colleagues (1997) who have proposed seven principles of effective scenario design for problem-based curricula. Briefly, they claim that scenarios should connect to the students' knowledge and experiences. Furthermore, they emphasise that scenarios should be complex but not overloaded or too structured. They should also relate to the forthcoming profession, encourage self-directed learning and present relevant basic science concepts. In addition, a scenario should enhance students' interest in the subject matter and match one or more of the faculty objectives. These authors do not problematise various conceptions of PBL and the examples all originate from medical curricula.

It is thus possible that the outlined principles might not be valid for scenarios in environmental science since the field of knowledge is different. One of the key features in this field is that its different players have different disciplinary perspectives that lead to different definitions of the problems. These different definitions themselves pose a problem for environmental science and the management of environmental problems. The overall objective of education in environmental science and consequently, the appropriate structure

of learning is thus that students should develop an ability to discern different perspectives and critically appraise them.

Most studies aiming to evaluate what makes up an effective scenario have focused on the relationship between student-generated learning issues and faculty objectives (Coulson & Osborne, 1984; Shahabudin, 1987; Dolmans et al., 1993, 1994). However, even though several texts emphasise the importance of purposive scenarios, few studies focus on how scenarios actually function during the learning process. We are well aware that several elements beside the scenarios influence student learning in a PBL context. Dolmans et al. (1994) showed that students' decisions about what to study were influenced by, for instance, the discussion in the tutorial groups, tests, course objectives, lectures, the tutor and reference literature. In this study, however, we have chosen to focus on the function of scenarios. In order to evaluate how scenarios function, it is necessary to describe the structure as well as the content of the questions evoked and their relevance in relation to the aims of the course.

The context of this inquiry

In August 1998, a new four-year problem based undergraduate programme in environmental science was launched at Linköping University, Sweden. The programme focuses on the complexity of environmental issues and the need for environmental scientists to be able to evaluate scientific and technical issues in relation to their social and cultural context. The overarching ideas and working methods are described in a programme handbook distributed to the students and available on the web (<http://miljo.ituf.liu.se>). Here, it is clarified how 'problems' are viewed within the context of the educational programme.

To begin with the 'problem' means in the context of the Environmental Science programme, that the students depart from a particular way of asking questions. Thus, a problem oriented approach involves formulating important questions surrounding a concrete environmental problem and taking a critical attitude towards the concepts used

to describe the problem. To begin with the 'problem' implies that the issues studied is not taken for granted, but rather seen in a context where the *interpretation* of the context (or contexts) is seen as essential for how a given problem is depicted. In summary, problem oriented teaching and learning are oriented towards *problematizing* that which is studied. How a problem is depicted and interpreted; thus, how a problem is created as a 'problem' in the first place involves a number of methodological issues and theories. These methods and theories are crucial throughout all the courses at the Environmental Science Programme

The programme handbook also provides the overarching objectives for all the courses included in the programme. The objectives of the course are formulated as the intended learning outcome and given as a document to the students at the start of the programme. The course objectives are aimed to function as a negotiable and flexible frame or guide for the students. Rather than being some kind of check-list, it is meant to be a tool that the students can use to attune their self directed learning as they proceed through course. It is emphasised that the students' prior knowledge and preconceptions are important as points of departure for their learning.

Throughout the programme, students are confronted with various scenarios. A mix of authentic environmental cases, constructed environmental cases and images or texts indirectly linked to authentic or constructed environmental cases such as comic strips, photographs, paintings, and newspaper headlines or articles are used. The scenarios are intended to stimulate learning and discussions of different perspectives of the problems and solutions related to the scenarios. The amount of time spent on each scenario varies throughout the programme from one to ten weeks. In the course studied here, the students worked with the scenarios during one to three weeks.

The aim of the study

The aim of the present study is to describe how scenarios used in an environmental science programme function in terms of the type of questions they evoked. The aim is also to illuminate students' reflections on the learning process. The study is based on written notes and reports focusing on the learning process produced by nine groups of students during a course. The course chosen is the ten-week introductory course in the environmental science programme at Linköping University (<http://miljo.ituf.liu.se/>).

Materials and method

The ten-week introductory course is called 'What is an environmental problem?' The overall aim was that the students should deepen their understanding of the complexity of environmental problems and start to discuss and problematise environmental issues. The students were also expected to develop an ability to problematise the following concepts: anthropogenic/natural, nature/culture, global/local, urban/rural, developed/developing countries, east/west and past/present/future. In addition, the students should become acquainted with the pedagogical model used in the programme.

The students met in their tutorial groups for two hours twice a week. The groups consisted of between 5 and 8 members under the supervision of a tutor (One of the authors of the present paper tutored two of the groups). Prior to the first meeting, the students are introduced to the working methods through the Programme Handbook, an introductory lecture and a discussion during the first meeting that is guided by the tutor. These three events all include the discussion of a conceptual model illustrating the different phases of the learning process.

The working procedure in the tutorials was typically that the scenario was handed out by the tutor and the group in question started to generate free associations with the scenario as the point of departure. Generally, the role of the tutor is to facilitate discussions rather than to be directive. Initially, a lot of effort devoted by the tutor to help the students conceptualise and recognise the different phases of the learning process. These interventions are most

prominent during the first scenario and gradually faded as the students learn to master the procedure.

The associations formed during the brainstorm were primarily single words or sentences. All associations were noted on the whiteboard without critical comments at this stage neither from the group nor the tutor. The group then proceeded to scrutinise and discuss the ideas generated in the brainstorming process in order to clarify their preconceptions. Finally, the ideas were arranged into themes that emerged through the discussion, and questions corresponding to the learning needs of the group were formulated. The next phase comprised of independent studies where the students sought for information in several ways. No mandatory course literature existed but the students had access to a comprehensive list of relevant books and articles. In addition, they sought information in for example the library, on the internet and through contacts with experts. This was done individually or together in pairs or smaller groups. After the independent studies, the group met again for discussion, synthesis and evaluation of what they had found. Their learning needs were reformulated by specifying new questions.

This was the first course of the programme and from the beginning it was not self-evident to the groups how to work with the scenarios. The relationship between the scenarios, the questions they evoked and the content of the studies can be described as iterative. In general, the groups started with their own associations and formulated their learning needs accordingly. The independent studies and the discussions that followed in the next session led to both a broadening and deepening of the content. In some cases this led to a reformulation of questions and in other a formulation of additional questions.

One of the objectives of the course is that the students learn how to chair and how to take notes during a session. These tasks are circulated among the students and is part of the regular course work. The notes can take any form approved by the group and are handed in to

the tutor at the end of the course. For the purpose of this study it was stressed that the notes should include the associations, categorisations and questions of the group. Later experiences have shown that students generally included these issues in the notes without being prompted to. The empirical material for the present study comprises the notes from all nine groups.

The material from the brainstorming in the groups was edited by the students themselves during the tutorial sessions. This means that the associations were grouped into themes, into which the group decided to inquire further. The discussions around the emerging themes gave rise to the formulation of learning needs in form of questions for self-study. The formulated questions make up the unit of analysis in this study. The results of the brainstorming were merely used by the authors as a help to understand the context in which questions were asked.

The data were subjected to a qualitative analysis aiming at describing the structure and content of the questions generated by the groups to direct the learning process. Categories were generated through the analysis and not defined in advance. The content of the questions was further described by utilising the notes from two of the groups to provide a more detailed account of how the students worked with the content. The reason for choosing these two groups was that one of the authors had been their tutor, which made it possible to make a more elaborated description of how the content was dealt with.

All comments quoted below were translated from Swedish into English by the authors.

The design of the scenarios

Five scenarios were subsequently used as separate points of departure for the learning process. The first scenario was a comic strip from the cartoon "Assar", drawn by the Swedish artist Ulf Lundkvist, and was used to introduce the whole course (Dagens Nyheter, 12 April, 1998). The comic strip consists of two drawings. In the first drawing, a man is standing behind a box of fish with a sign reading *ecological fish* and a woman asks *what does this*

mean? In the second drawing, the man answers: *They all died a natural death*. The second scenario was the front page of a brochure published as a report by the Swedish environmental protection agency, dealing with protected arable land (Naturvårdsverket, 1997). The cover depicted a typically Swedish pastoral idyll showing a red cottage in a fenced meadow with a small gate. The heading ran across the picture and the logotype of the agency was placed in the upper left corner. This scenario was intended to stimulate discussions in relation to the concepts natural/anthropogenic and nature/culture. The third scenario was a pencil drawing, the aim of which was to highlight the concepts global/local and urban/rural. The drawing portrayed a van meeting a bus full of passengers on a country road. The van has a picture of a cow on the side with the word *Milk* running above. The fourth scenario was the front page of a magazine (EcoForum, 1997) intended to relate to the concepts developed/developing countries and east/west. The cover pictured a large hand coming out of a cloudy sky and pointing a giant finger at a huge note in front of a number of people who obviously come from different parts of the world. The text on the note is illegible but the words *Agenda 21* can be deciphered. The scenarios two to four were each used for two weeks. The fifth scenario was used for three weeks, and consisted of an old saying, *Those were the days*, which was typed on a piece of paper and related to the concepts past/present/future.

[Insert figure 1 about here]

Results

Our analysis generated the following five categories of questions that were labelled *A. Encyclopaedic questions*, *B. Meaning-oriented questions*, *C. Relational questions* and *D. Value-oriented questions*.

A. Encyclopaedic questions

The encyclopaedic questions are formulated in a way that suggests that the students expect to find an unambiguous and not too complex answer. Typically, the lexical meaning or criteria of a certain term or phenomenon is asked for. The questions pertaining to this category are characterised by a kind of uni-dimensionality in the sense that they contain only one aspect, which is often quantitative. The meaning of the term or phenomenon in a deeper sense is not asked for. In some cases, the questions are formulated in such a way that they may be answered with a 'yes' or 'no'. The phrasing is also typically characterised by the use of interrogatives such as 'who', 'what', 'which', 'where'. Examples of this type of question are:

How long has the environmental protection agency existed? (Group 1, scenario 2)

How much pollution do we export/import? (Group 7, scenario 3)

What criteria make a country a developing country? (Group 3, scenario 4)

Who controls the KRAV certification? (organic farming, authors' remark) (Group 2, scenario 1)

Are cultivated land and arable land the same thing? (Group 5, scenario 2)

What energy sources have been used through the centuries? (Group 6, scenario 5)

B. Meaning-oriented questions

In this category, the questions are typically oriented towards finding the phenomenological meaning of certain terms or concepts. The context reveals that the students do not expect to find a direct answer in, for example, an encyclopaedia or dictionary. The terms focused on are often defined or problematised in relation to other terms. Typical question words used in this category are: 'what is the meaning of', 'what is', 'why'.

What does a natural death mean? (Group 8, scenario 1)

Is there anything that is natural? (Group 3, scenario 2)

What problems arise when we define the term ecological? (Group 1 scenario 1)

Why is transportation the way it is? (Group 3, scenario 3)

What is development and for who or whom is it intended? (Group 8, scenario 5)

C. Relational questions

The relational questions contain more than one aspect and the relationship between these aspects. Typically, they aim to explain causes or to lead to an understanding of the consequences of a certain phenomenon. Causal as well as general relationships are emphasised. The questions deal with rather complex contexts with multiple dimensions. Typical nouns included in the questions are 'influence', 'effect', and 'consequence'. The following excerpts exemplify this category;

What are the effects of urbanisation? (Group 8, scenario 3)

What influence does the cultural landscape have on biological diversity? (Group 2, scenario 2)

What political instruments of control have given Swedish agriculture its present form? (Group 4, scenario 3)

What are the consequences of our transportation from a food perspective and a personal perspective? (Group 5, scenario 3)

What environmental consequences will our trade agreement with the EU have? (Group 7, scenario 3)

Which conditions are needed to create sustainable development? (Group 6, scenario 4)

D. Value- oriented questions

The value-oriented questions are comparative in nature. They aim to evaluate environmental consequences in terms of better or worse. Searching for norms on which to base judgements is a central feature, although it is clear that the students do not expect to find supreme norms. On the contrary, the questions give the impression that the students should search for answers that will enable them to develop value-based standpoints. These questions sometimes expand outside the learning context of the course to include existential issues. Typical value-oriented words used in the phrasing are 'what is good', 'what is bad', as exemplified below;

What types of transportation are good/bad for the environment? (Group 8, scenario 3)

What type of energy sources would be best for the future? (Group 6, scenario 5)

Do the developing countries benefit or lose from the activities in developed countries?

(Group 9, scenario 4)

Are activities in the developed countries good or bad for the developing countries?

What culture ought to be conserved and why? (Group 1, scenario 2)

E. Solution-oriented questions

The focus of the solution-oriented questions is the management of environmental issues rather than a search for the meaning of different aspects of these problems. Typically, the questions deal with large and complex problems on an abstract level and the students seem to look for concrete solutions. The phrasing contains typical verbs such as 'do', 'diminish', 'change', 'distribute'. The following questions are typical of this category;

What can we do about the fish problem? (Group 6, scenario 1)

What can we do to reduce the volume of transportation? (Group 8, scenario 3)

How can we change our behaviour in order to achieve global sustainable development?

(Group 9, scenario 3)

How does one construct an ecological society? (Group 5, scenario 5)

Frequency and distribution of questions

Analysing the material longitudinally did not reveal any obvious patterns since all types of questions were asked with about the same frequency throughout the course in all of the groups. In only a few cases, the groups asked for the definition of terms originating from the objectives in the programme handbook. One interpretation is that the students did not problematise the scenarios from their own experiences and preconceptions, but rather used the objectives as a check-list for their learning. On the other hand, the ways the majority of

the questions were phrased, indicate that they were generated from the students' associations in the tutorial group rather than being taken directly from the objectives of the course.

All scenarios generated questions pertaining to all five categories in all the groups, although the emphasis varied. In relation to the overall pattern described above, there was an emphasis on meaning-oriented questions in the first scenario (the comic strip) whereas the second scenario (the photograph) generated relatively many encyclopaedic questions. Further, the third scenario (the pencil drawing) generated exceptionally many solution-oriented questions while there were relatively few meaning and the value-oriented questions. None of the categories stood out in the fourth and fifth scenarios (the magazine front page and the old saying).

All in all, the edited material from the brainstorming in the tutorial groups generated 234 questions, of which ten (4%) were too fragmentary to be categorised. The encyclopaedic category dominated, representing about one third of the total number (31%). The meaning-oriented and the relational categories were equally large (24%) and together account for almost half the questions, while the value-oriented category was slightly smaller (11%). The solution-oriented category was the smallest and accounts for the remaining questions (6%). Encyclopaedic and relational questions were asked in approximately 70 percent of all the occasions. Meaning-oriented questions were asked almost as often (60 percent), followed by the value-oriented questions which were asked in about 50 percent of all the occasions. The least frequently asked questions (solution-oriented) were asked on about every fourth occasion. There was a slight variation among the groups regarding number and type of questions and their relative frequencies over the categories.

The content of the questions

The different scenarios functioned slightly differently with regard to how the groups problematised and related them to the curricular aims. In order to provide a more in-depth description, an account of how two of the groups worked with two of the scenarios is given.

The introductory week was followed by a two week-period aiming at bringing the concepts natural/antropogenic and nature/culture into focus. At the onset of this period, the scenario presented to the students was the photograph from a brochure published by the Swedish environmental protection agency. The students in both groups started to associate with the heading and the logo as their point of departure but after a while they focused on the picture itself. One of the groups gradually developed their understanding of the concepts *nature* and *culture* which is demonstrated by their formulating and reformulating questions related to the concepts. A movement back and forth from relational to meaning-oriented questions is discernible as indicated by the quotation below.

Which role does nature play in Swedish culture?

What is nature? What is culture?

What is nature in relation to culture? (Group 8, scenario 2)

At the end of the period the group evaluated their work with the following conclusion:

We agree that we have learnt quite a lot about protected arable land, nature reserves, conservation areas, the environmental protection agency and the concepts nature and culture

The other group adopted a more taken-for-granted approach to the concepts and did not explicitly discuss their inherent meaning. Instead, they indirectly problematised the use of the concepts 'nature', 'natural' and 'culture' by putting them in context as indicated below:

What is natural in Swedish agriculture?

What type of environments do we protect and why?

Why do we think that they are worth protecting? (Group 6, scenario 2)

The following part of the course was also two weeks long and its aim was to problematise the use of the concepts urban/rural and global/local. The scenario was a pencil drawing of a bus full of passengers meeting a truck transporting milk on a small country road. Again, one of the groups worked by means of a process of formulating and re-formulating their questions, moving back and forth between different types of questions. Following some questions clearly related to the pair urban/rural – without, however, explicitly using these words – such as: *What is counted as countryside?*; *Why do people move to cities?*, the students formulated the question *What is urban/rural?* and introduced the term urbanisation in their notes. It is quite clear that the students did not form associations with any issues related to the concepts local/global. Instead, the association *distance* was used as a point of departure for the question *World trade (short and long-distance transportation)?*

The other group formulated a number of questions which were initially directly related to the use of the concepts urban/rural as well as local/global, for example:

Transportation (who/what) to and from city-countryside. Effects.

Why do people want to live in cities (and move from the countryside)?

What can be done to reduce transportation?

Local-global transportation (Group 6, scenario 3)

When determining which questions to focus on when searching for information, the group only included questions related to the concepts urban/rural. The group read quite a lot of literature, conducted analyses and thoroughly discussed environmental problems within this area. However, in session three they noted that they had excluded the concepts local/global as commented on in their evaluation:

We reach the conclusion that the exchange between city and countryside has been sufficiently discussed. But there is another pair of concepts among the curricular aims that we have not studied sufficiently — the local/global. We found it difficult to tackle

the question *Why do we not trade locally?* and we discussed different aspects of the problem area. (Group 6, scenario 3)

The design of the scenarios also appears to have influenced the types of questions generated. It is striking that any text present in the scenarios often seemed to have caught the students' attention first while other features of the scenarios received more attention later in the process. In, for example, the first scenario, the words 'ecological' and 'natural' were used in a large number of the questions. Similarly, in the second scenario, questions concerning the Environmental protection agency, etc., dominated.

Reflections on the learning process

The groups' reflections on their learning process given in the reports give a picture of how they experienced their development. One of the groups described how they had learnt how to be critical and questioning, how to explain, listen, and facilitate discussions in the group. At the beginning of the course, the students found that the work in the tutorials did not stimulate discussion and reflection since they basically only reported facts that they had found in the literature. The group was not satisfied with this, as reflected below:

When the people in our group presented their material in the tutorials it was in the form of reports. It became 'that's the way it is' presentations that were not designed to initiate discussions or questions. We believe that this was because we ourselves did not question what we had read /.../ We have learnt that the questions that we direct to each other in the group make us reflect and explain what we mean, and that this makes the learning deeper. At first, we were almost afraid of the questions we were asked. You got the feeling that the other group members thought that you had not read enough if you could not answer properly. But we have now discovered that the questions help us make progress. (Group 6)

At the beginning of the course, you concentrated so much on what to say yourself that it was impossible to listen to what the others had to say. Now, we feel that we have learnt to relax and listen. (Group 6)

The group describe how they had eventually learnt to formulate their questions and to share the knowledge they have gained with each other in a better way by using more open-ended statements:

We have reached the conclusion that the presentations should be short and designed to initiate a discussion. /.../ Some ways of doing this are to say ‘this book suggests ‘ or ‘this made me want to ask’ If we can initiate discussion in the group in this way we can save time (Group 6)

The other group also reflected on their development but focused more on the difficulties in formulating questions and delimiting the learning tasks in a way that was relevant to the objectives of the course:

We made a lot of effort to define the meaning of different concepts, especially at the beginning of the course. Words with meanings that previously were self-evident, like nature, environmental degradation, culture, etc. were discussed back and forth until we were totally confused. Gradually, we have realised how complex these concepts are, and have reached the conclusion that there are hardly any simple answers or explanations of words and concepts. This understanding has, in turn, helped us when we have formulated our questions. (Group 8)

This group also reports on how the group adopted different procedures during the course. From the beginning, all members of the group worked with all the questions that had been formulated, practising the principle that everybody should learn everything.

Most of the time, we chose at least one text that everybody had to read, and this led to very fruitful discussions. Even if everyone has read the same text, they each have their own interpretation of the content. One learns a lot by hearing how different people think about and react to a text.

At the end of the course, the group changed their working procedure by distributing their questions among the group. anent

Altogether, the group probably gathered more facts during this period than during the previous ones, but the question is whether we learned more. We found that the discussions weren't as good as during the other tasks, since we didn't know anything about what the others had read. The tutorials became more like reports, where everyone reported what they knew to the others. We found that we did not use the group as effectively as before.

The concluding remarks from the group stated that the introductory course had given them new perspectives that they felt would be of value for the rest of their education and for their professional work. They claimed that one of the most complicated tasks they had to deal with during the course was pondering on *how one learns* since it was difficult to really pinpoint this.

Our study shows that the scenarios chosen for the introductory course functioned very well as a point of departure for learning environmental science. The scenarios functioned differently, but the questions and the content studied were relevant and sufficient in relation to the objectives of the course. The students clearly expanded their search for cognitive knowledge to embrace a wider context than just the chosen example, and made links to other situations relevant to environmental science. They also managed to discern and discuss different perspectives of the problems generated from the scenarios.

Discussion

Complexity versus perplexity in the design of PBL scenarios

One of the principles for effective case design put forward by Dolmans and colleagues (1997) is that the scenarios should contain enough but not too many cues to enable students to elaborate their discussions. In our interpretation, this suggests that complexity is an

important feature of scenarios. The first (the comic strip), second (the pastoral idyll) and fourth scenarios (the big hand holding a note in front of people from different parts of the world) were rather complex and the students did problematise them in depth in line with the course objectives. On the other hand, the third scenario (the bus and the milk van) appeared to contain too few cues to be properly problematised. As a result, the students focused mainly on transportation issues, which were only one of the major objectives of the course. This observation supports the notion of complexity as an important feature of a well-functioning scenario.

However, the fifth scenario (the old saying) comprised only one sentence, thus containing very few cues and this scenario worked as well as the others. This indicates that it is not complexity in itself that constitutes a fruitful scenario. A closer look suggests, instead, that scenarios that were *provocative* or evoked *emotional involvement*, for instance, by containing a certain opinion or some kind of contrast or tension, were powerful triggers. This brings to mind Koestler's paper on the act of creativity (1981) in which he claims that a contrast or tension occurs when logics from different contexts, which are not usually connected to each other, are combined. Koestler labels this *bisociative*, in contrast to associative thinking, which he defines as thinking according to given sets of rules and encompassing logic from one context only. Koestler considers the bisociative act as the essence of creativity. This is well in line with the arguments presented by Russell (1999), drawing on the writings of Dewey (1933), who claims that *perplexity* is one of the defining features of reflective thinking and problem involvement. Reflective thinking involves

- ..(1) a state of doubt, hesitation, perplexity, mental difficulty in which thinking originates,
- and (2) an act of searching, hunting, inquiring, to find materials that will resolve the doubt, settle and dispose of the perplexity (Dewey, 1933, p.12, cited in Russell, 1999)

Russell suggests that the affective state of perplexity in the learner has been overlooked as an important feature of problems in problem-based learning. He also argues that problems in

PBL often lack this feature. In many cases, the problems serve the purpose of directing the students towards the acquisition of knowledge of something specific, rather than 'finding its focus on the problem of the problem' (p. 185). In Russell's opinion, a good problem in PBL could be described metaphorically as an irregular plait, in which each strand becomes a significant bearer of meaning, although it is not self-evident from the outset how this meaning could be disentangled. The problem resists reading and causes perplexity in the learner, he argues, since it lacks the clarity and regularity that we are used to looking for when reading a textbook. According to Russell, texts have the features of a woven fabric, meaning that they have a regularity of form, in which the horizontal (incidents) and vertical (plot) features are identifiable. These features, he argues, are to be found in textbooks that formalise the body of knowledge within a certain field of study. A problem used in PBL should, rather, have the opaque characteristics of a plait than the transparent structure of a woven fabric.

Another point put forward by Dolmans et al (1997) as a principle for designing effective scenarios for PBL, is that the cases should present 'relevant basic science concepts'. In the Environmental Science programme the issue of 'relevant basic science concepts' is interpreted slightly differently. Here, the emphasis throughout the course is put on concepts that are central to environmental science, but could be differently interpreted from different perspectives. These concepts also provide the structure to the introductory course as a whole. One of the central aims of the whole programme is to enable students to discern and problematise differences in perspectives and the consequences they bring to the analysis of environmental science problems. Hence, the basic or central concepts are not always included in the scenarios as such, but the results of the study show that the questions formulated by the students in several ways relate to these concepts.

Our data also reveal that learning issues in some cases were generated from the course objectives rather than from the discussion about the scenarios. This finding is to some extent in line with Dolman and colleagues' (1994) study of what elements in PBL perpetuate the students' learning. The influence of the discussions in the tutorial groups on students' decisions of what to study tended to increase over a four-year programme. In our study, however, the influence of the discussions in the tutorial groups appears to be important for the formulation of learning needs from the very outset of the educational programme.

Variation as a prerequisite for learning

A prerequisite of learning is, according to Marton & Booth (1998) and Bowden & Marton (1999), that the learner must be able to discern aspects or dimensions of phenomena in the surrounding world by experiencing variations in these aspects or dimensions. Marton (1999) even argues that without variation, there is no discernment and no learning can take place. Experiencing certain patterns of variation is also necessary, he argues, in order to develop certain ways of seeing, for instance, the certain ways of seeing pertaining to a specific profession. Variation is also, according to Marton, the key concept as regards preparing students for as yet unknown learning communities of the future. The only way to prepare for variation is by means of experiencing variation, he argues. In order to accomplish this, Marton advocates that teachers should arrange conditions for learning and use forms of teaching that expose students to a relevant variation. In the present study, it is quite clear that a wide variation was generated in how the learning task was formulated by the students. This variation also comprised differences in discerned aspects, pertaining to different perspectives and areas of knowledge, that the students considered relevant to the field of study. This leads us to the conclusion that the students themselves created a relevant variation through their work with scenarios in the tutorial groups.

Approaches to learning

The different kinds of questions generated by the scenarios are different in nature but, nevertheless, provide a picture of the students' approaches to learning. Differences between approaches to learning are, as Bowden and Marton (1998) put it, differences in what the learners are focusing on, what they are trying to achieve and how they are going about it.

When adopting a *surface approach* to learning, the learners are focusing on surface characteristics of the situation, on the very wording of a text being read, of the argument put forward, on figures in a problem, on formulas to be used for solving the problem. /.../

When adopting a *deep approach* to learning, the learners are focusing on the object of learning, they are trying to get hold of the phenomenon dealt with in the text they are reading or in the presentation they are listening to. In problem solving they are initially trying to grasp the problem (p. 8)

Making use of only encyclopaedic questions could indicate a surface approach learning, looking mainly for the lexical meaning of a word a concept, while the use of meaning-oriented, relational and value-oriented questions could indicate a deep approach to learning. In this study, even though the encyclopaedic questions were relatively large in number, none of the groups asked this type of questions as their only way of working through any of the scenarios. Instead, the typical pattern was a dynamic process, moving back and forth between encyclopaedic questions and meaning-oriented or relational questions.

The students' ways of working through the scenarios bring us to assume that all the five types of questions described here are necessary to bring about meaningful learning. The scenarios seem to generate a context in which encyclopaedic questions are naturally linked to meaning-oriented and relational questions in an integrative process. Thus, the description of how the scenarios function could also be interpreted as an empirical example, supporting Margetson's theoretical reasoning about a "growing web" conception of the role of problems in knowledge and knowledge acquisition in PBL.

Here, we have focused mainly on the process of working through the scenarios and our findings may shed some light on the ways questions for learning are formulated in a PBL programme within environmental science. Whether the questions formulated have any impact on the approaches to learning adopted by the individual student, and what the influence of the different kinds of questions asked are on the outcome of learning is an issue that needs to be further explored in forthcoming studies.

Acknowledgements. The authors gratefully acknowledge our colleagues at the Centre for Learning and Teaching, the Department of Environmental Science, and the Referees and the Editor of this journal for all helpful comments that contributed to the improvement of this paper. The authors also wish to acknowledge the Centre for Learning and Teaching, Linköpings Universitet, for funding this research.

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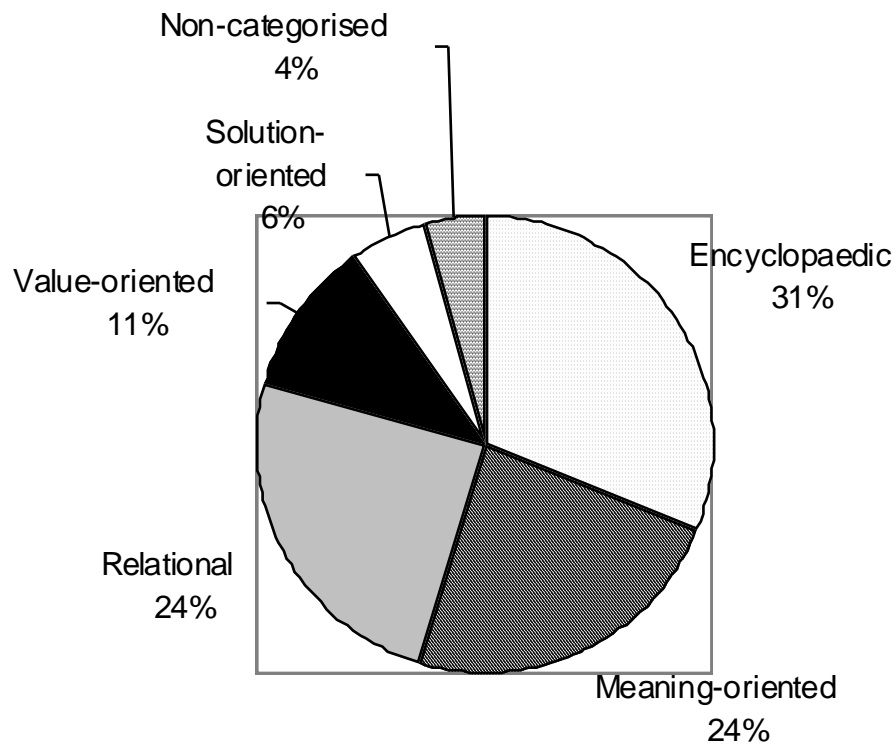
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Scenario	Format	Description	Aiming at problematising the concepts

1	Comic strip	A man is standing behind a box of fish with a sign reading <i>ecological fish</i> and a woman asks <i>what does this mean?</i> . In a second drawing, the man answers: <i>They all died a natural death.</i>	Whole course
2	Front page of a brochure	Depicting a typically Swedish pastoral idyll showing a red cottage in a fenced meadow with a small gate. The heading ran across the picture and the logotype of the agency was placed in the upper left corner.	Nature/Culture, Antropotenic/Natural
3	Pencil drawing	A van meeting a bus full of passengers on a country road. The van has a picture of a cow on the side with the word <i>Milk</i> running above	Urban/Rural, Local/Global
4	Front page of a magazine	A large hand coming out of a cloudy sky and pointing a giant finger at a huge note in front of a number of people who obviously come from different parts of the world. The text on the note is illegible but the words <i>Agenda 21</i> can be deciphered.	Developing/Developed countries
5	Old saying	The sentence <i>Those were the days</i> , typed on a piece of paper	Past/Present/Future

Fig. 1. Frequency and distribution of questions



Legend to table 1:

Description of scenarios used in the introductory course of the Environmental Science Education Programme