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Author(s)	Christine Chin and Chia Li Gek
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PROBLEM-BASED LEARNING: INSPIRATIONS FOR STUDENTS' PROBLEMS AND QUESTIONS ASKED

Christine Chin
National Institute of Education, Nanyang Technological University

Chia Li Gek
Curriculum Planning and Development Division, Ministry of Education, Singapore

Abstract

This case study involved secondary 3 students carrying out project work in biology via problem-based learning. The purpose of the study was to find out (a) the sources of inspiration for students' problems and questions, and (b) the kinds of questions that students asked. Students first identified their own problems for investigation and then worked in groups to solve the problem. Data sources included observations of students at work, interviews, students' written work, and tapes of students engaged in group work. Students' problems and questions were inspired mainly by cultural beliefs, the media, personal experiences, and the school curriculum. Students' questions directed their learning and guided them to engage in different activities which led to knowledge construction. Implication of the findings for instructional practice are discussed.

One of the initiatives implemented as part of the Ministry of Education's vision of "Thinking Schools, Learning Nation" is project work. Although project work is not a new feature in local classrooms, it tended to be highly structured in the past. The key weakness of highly structured tasks is that not much thinking is generated. Little construction of knowledge is attained when groups engage in project work which merely compile and present information that they have copied from books, other media resources, or experiments. One way to address this concern is to use problem-based learning and model the projects after real-life problems.

Problem-based learning (PBL) is an instructional model where problems act as the stimulus and focus for student activity and learning (Boud and Feletti, 1991). Learning in this way is purposeful and self-motivating as the student learns while searching for solutions to the problems. Students are actively involved and learn in the context in which knowledge is to be used. Features of PBL include initiating learning with an ill-structured problem, using the problem to structure the learning agenda, using the instructor as a metacognitive coach, and working in collaborative groups (Gallagher, Stepien, Sher and Workman, 1995). In PBL, the information that students gather for the unit of study is learnt for the purpose of solving a problem. Thus, problems are introduced at the beginning of a unit of instruction, unlike traditional teaching methods which introduce problems only after students have learnt the necessary body of knowledge. The "problem-first" approach in PBL ensures that students know why they are learning what they are learning, hence increasing intrinsic motivation for learning.

The teacher guides by first modelling and coaching. Students then take on the responsibility of using the skills on their own. That is, teachers take on a facilitating and supporting role instead of behaving as experts who have "right" answers to the problem. It is important to allow the students to make their own decisions about the directions that they will

take in their investigations, what information they will need to locate, and how they will analyze and evaluate the information to understand and then resolve the problem.

Working in collaborative groups allows students to construct knowledge when they engage socially in talk and activity about shared problems or tasks (Vygotsky, 1978). Because the problems encountered are situated in real-life contexts, students are also better able to form connections between the science they encounter in their textbooks and the science that is required to solve real-world problems (Yager, 1989).

The first step in PBL is problem discovery or identification. Where do students get inspirations for their problems? Keys (1998) found that students' ideas for their problems can arise during the teacher's pre-planned activities. These can surface spontaneously from group discussions about experiences with previous science lessons and everyday life. Inspirations for students' problems can also come from (a) curious events, or observations that cannot be explained easily, (b) data gaps, or failure to find observations that have been predicted by a theory or law, and (c) chance observations (Wilson, 1974). Other sources of students' ideas for investigative problems include contemporary issues of interest rooted in scientific and humanistic traditions (Stinner, 1995), events in family life, significant hobbies or interests (Tytler and Swatton, 1992), and societal issues (Dunkhase and Penick, 1990). Whatever the source, the process of problem discovery often stems from students' interactions with real-world issues, and the desire to find out something relevant to their personal lives.

Students' questions play a crucial role in the learning process, and a range of questions are asked during the search for the "problem space" (Newell and Simon, 1972) and when looking for a solution to a problem (Gallagher, Stepien, Sher and Workman, 1995). Questions raised by students activate their prior knowledge, focus their learning efforts and facilitate the understanding of new concepts, help them elaborate on their knowledge, and arouse their epistemic curiosity (Schmidt, 1993). As students work with their peers in groups, their questions can stimulate themselves or their group members to hypothesize, predict, generate explanations for things which puzzle them, and reflect on their own ideas. This can engender productive discussion, thereby leading to meaningful knowledge construction (Chin, Brown, and Bruce, 2002). Student-generated questions also help diagnose students' understandings (Watts, Gould, and Alsop, 1997) and reveal their conceptual difficulties (Maskill and Pedrosa de Jesus, 1997).

Purpose and Significance of Study
As an instructional model, PBL has great potential in promoting inquiry in science classrooms. However, the use of this approach is relatively new in schools and not much research has been done in this area. Our understanding of how students respond when asked to formulate their problems, pose their own questions and design investigations to answer them, is still relatively limited. The purpose of the study was to investigate students' inspirations for their self-identified problems, the types of questions asked, and how students' questions guided them in knowledge construction. The research questions were:

1. What are students' inspirations for their problems and questions?
2. What kinds of questions do students ask during the initial problem-identification phase?
3. What kinds of questions do students ask during the problem-solving phase, and how do these questions guide them in knowledge construction during the problem-based learning process?

Because students' questions play a significant role in meaningful learning and motivation (Chin, Brown, and Bruce, 2002), the elucidation of the kinds of questions asked, as well as the inspirations for their questions could inform teachers of the kinds of puzzlement and wonderment that students have, and how these relate to students' daily lives. This is important because teachers can then be more aware of what students are interested in and what they want to know about a given topic. In this way, teachers can be more responsive to students' needs and interests, and tailor their instruction to cater to these individual differences.

Design and Methods

The 18-week study, which focused on the theme "Food and Nutrition", took place at an all-girls secondary school. The second author was the science teacher. The class of 39 students worked in nine groups of four to five each which were heterogeneously mixed in terms of ability.

Each group worked on a project topic of their choice related to the given theme. One 35-minute period per week was specifically set aside for students to work on the project. During the remaining four periods each week, the teacher integrated students' project work ideas and findings into her lessons which focused on enzymes, nutrients and classes of food, a balanced diet, nutritional deficiency diseases, animal nutrition, and plant nutrition. For example, at different points in the lessons, teams of "expert researchers" who investigated the different aspects of Food and Nutrition, were asked to share their knowledge of the topics and issues that were being raised. These included food tests, causes of obesity, the relationship between obesity and heart disease, and dentition.

Stages of Implementation

The students went through five consecutive stages: (1) Identifying the problem to be investigated, (2) Exploring the problem space, (3) Carrying out scientific inquiry, (4) Putting the information together, and (5) Presenting the findings, teacher evaluation and self-reflection.

In stage 1, the students identified the problem to be investigated. They first wrote down their ideas and questions individually onto problem logs. Then they discussed their ideas in groups, agreed on a topic, and jointly formulated their problem. In writing their problem statements, the students were encouraged to take on real-life problem-solving roles. In stage 2, the students organized their ideas around three focus questions using a "Need-to-Know" worksheet (Gallagher, Stepien, Sher and Workman, 1995). The questions were: (a) What do you know? (b) What do you need to know? (c) How can you find out what you need to know? The students regularly recorded their ideas and questions onto this worksheet. The students also identified the resources that they had to use and the type of tasks they had to engage in, to solve their problem.

In stage 3, the students gathered information to answer their own questions. The teacher set up an Internet forum page ("e-circle") for students to consult a panel comprising a doctor, a dentist, a nurse, and a medical research worker. Students used this platform to ask questions related to their research. Some of the groups used the science laboratory to carry out their investigations. Others consulted experts, went on field investigations, conducted surveys and interviews, and looked up information from print and electronic resources.

In stage 4, the students reported on what they had done, completed further Need-to-Know worksheets, and planned for further tasks. The students documented their questions, filled in learning logs where they recorded what they had found out and the science concepts learnt, as well as planned ahead for the next step in their inquiry. This helped them to review and to consolidate the information gathered. In stage 5, each group gave a 15-minute oral presentation followed by a question-and-answer session. All the presentations were videotaped. All the groups used technology-based multimedia modes of delivery and some submitted artefacts. The students also submitted a group project file which documented the group's findings and details of the inquiry process.

Data Collection and Analysis

Guiding "thinksheets" in the form of planning forms and reflection logs were widely utilized not only to facilitate student knowledge construction, but also to capture students' thinking processes and to record their progress. Together with students' project files, these documents also served as data sources for subsequent analysis. The students were observed during project work sessions and field notes were taken.

Groups were selected, in turn, for audiotaping and videotaping during interactive discussions and hands-on activities. The students' taped discourse during these class activities were transcribed. Students from each group were also interviewed twice to find out the sources of inspirations for their problems and what they had learnt during the course of their project work. The first interview was conducted immediately after the groups had framed their problems. The second interview was carried out towards the end of the project work.

Data on sources of inspiration for students' problems were obtained mainly from interviews and classroom discourse. To identify the types of questions that students asked individually during the problem identification phase, all the questions written by the students in their problem logs were compiled and then analyzed for their content and nature. Coding categories (Bogdan and Biklen, 1992) were developed, based on an inductive analysis of the questions. To identify the kinds of questions that students asked collaboratively on a group basis during the inquiry process, questions captured in the Need-to-Know worksheets were analyzed.

To infer the role that these questions played in the inquiry process, data from the students' oral presentations and their group project files which documented details of what they thought and did, were analyzed. Segments of the group discourse transcripts related to these questions were also scrutinized to study the evolution and progress of students' thinking, behaviors, and actions during their knowledge construction process. Assertions were made based on patterns observed which were grounded in the data.

Results

Inspirations for Students' Problems and Questions

Sources of inspiration for students' questions and problems included: (a) cultural beliefs and folklore, (b) wonderment about information propagated by advertisements and the media, (c) curiosity arising from personal encounters, family members' concerns, or observations of others, and (d) issues arising from previous lessons in the school curriculum.

Several of the questions and problems inspired by cultural beliefs and folklore were influenced by ideas or myths that were socially transmitted by word-of-mouth in the community. Some students were curious about the use of Chinese herbs for body nourishment. Others related to the following beliefs: monosodium glutamate (MSG) in foods causes hair loss, jumping around after a heavy meal causes appendicitis, eating durian and drinking brandy at the same time would kill the consumer, and consumption of black soy sauce during pregnancy would produce a dark-skinned baby. The students wanted to validate if some of these beliefs could be explained scientifically.

Some students were curious about information that they had come across in articles or advertisements from the media. For example, advertisements by slimming centers, pharmacies, and hair treatment salons elicited questions such as "What is present in slimming pills that can cause people to slim down?" and "Can herbs cure hair loss?". Reports in the newspapers on drug abuse and health issues gave rise to questions such as "How does the food we eat lead to cancer?" and "Why does too much MSG affect our health?". Reports on the use of Viagra to treat impotence had some students wondering whether impotence could be cured by eating certain foods. A slightly overweight girl was intrigued by beautifully shaped bodies in weight-loss advertisements and wanted to do a project on "Slimming Centres."

The students were also motivated by curiosity related to their personal experiences involving family members' concerns or observations of other people. For example, one student had a father who was deeply concerned about his hair loss problem and she wanted to do a project on "Hair Loss". Another student was worried about whether chewing betel nut was detrimental to the health of her grandmother who had kept the habit for years, and wanted to find out more about this. Yet another student suggested a project on "Ginseng" as she had been drinking ginseng tea made by her mother who believed that it had "cooling effects" on her and that it would "help her do better in her studies".

Some questions and inspirations for problems were derived from students' prior knowledge and previous encounters during school-based lessons. For example, an article on "Weight loss program" that the teacher had used earlier elicited questions such as "What are fats?", "What is cholesterol?", "If someone loses weight very quickly, can she also gain weight as quickly?". Another student who had been told by her Home Economics teacher during a cooking lesson that eating too much monosodium glutamate (MSG) would make one's hair drop was eager to find out whether this was true or not.

Questions Asked Individually during Problem Identification
In total, 129 questions were collated from 35 individual problem logs. Four students (10.3%) did not hand in their problem logs. Table 1 shows how the students' individual questions could be grouped under four broad categories: validation of common beliefs and misconceptions, basic information, explanations, and imagined scenarios.

Questions that revolved around common beliefs and misconceptions typically asked for some validation (e.g., "Does doing hula-hoop make your waist smaller?"). Cultural beliefs and folklore were the source of most of these questions. Others reflected students' misconceptions in their understanding of biological concepts. Examples include "Will the person who has one kidney donated away have difficulty in excreting faeces?" and "How do we convert fat to muscles?". The misconceptions that surfaced served to guide the teacher to address some of these issues at an appropriate time when teaching the topic.

Table 1. *Types of Student-generated Questions Asked Individually*

Type of Question	Examples
Validation of common beliefs and misconceptions	• Does doing hula-hoop make your waist smaller? • Does eating after 8 pm make you gain weight easily? • Does taking chilli [pepper] cause pimples? • How do we convert fat to muscles?
Basic information	• What kind of sugar do some sweets labeled "sugar-free" use? • What is cholesterol? • What diet do sumo wrestlers keep? • How do people get food poisoning?
Explanations	• Why do our stomachs growl when we are hungry? • Why does sweet food spoil our teeth? • Why is it that most beer consumers have pot bellies? • How does the food we eat lead to cancer?
Imagined scenarios	• What happens to a body which experiences long term starvation? • If we do not eat carrots, will we go blind? • What happens if one kidney is donated away? • Does exercising too much cause harm to the body?

Questions that demanded basic information required only simple information-gathering and more straightforward answers (e.g., "What is cholesterol?) . Such questions typically related to factual information and the answers could be found simply by referring to books or asking someone. Questions that sought explanations tended to target at cause-effect relationships and mechanisms of action that relate to the human body (e.g., "How does the food we eat lead to cancer?"). Questions that dealt with imagined scenarios sought answers to a supposed happening (e.g., "What happens if one kidney is donated away?") and encouraged students to postulate hypotheses.

Table 2 shows how students' questions were distributed by type and source of inspiration. The majority of questions raised (54.2%) were asked in pursuit of basic information. About a quarter of the questions (26.0%) sought explanations for previously observed phenomena. The remaining questions sought to check if certain common beliefs could be validated (10.4%) or pertained to imagined scenarios (9.4%). A large number of questions were stimulated by sources outside of school. Personal encounters, family members' concerns, and observations of other people accounted for about half (48.0%) of the questions, while another quarter (25.0%) had their origins in the information propagated by advertisements and the media. Cultural beliefs and folklore gave rise to 13.5% of the questions. Only a mere 13.5% of the questions were inspired by ideas from the school curriculum.

Questions which stemmed from ideas related to the school curriculum all fell under the category of basic information. Not surprisingly, questions related to the validation of common beliefs and misconceptions arose mainly from cultural beliefs, folklore, personal encounters, family members' concerns, and observations of others. A large proportion of the

questions pertaining to explanations and imagined scenarios, which were pitched at a relatively higher order of thinking, were inspired by personal encounters, family members' concerns, and observations of others (19 out of 25 questions for "Explanation" questions, and 6 out of 9 questions for "Imagined scenario" questions).

Table 2. *Distribution of Students' Individual Questions by Type and Source of Inspiration*

Source of inspiration	Number of questions				
	Validation of common beliefs and misconceptions	Basic information	Explanations	Imagined scenarios	Total
Cultural beliefs and folklore	7	4	2	0	13 (13.5)
Information propagated by advertisements and the media	0	17	4	3	24 (25.0)
Personal encounters, family members' concerns, and observations of others	3	18	19	6	46 (48.0)
School curriculum	0	13	0	0	13 (13.5)
Total	10 (10.4)	52 (54.2)	25 (26.0)	9 (9.4)	96

Note. Numbers in parentheses indicate the percentage of the total number of questions.

Questions Asked Collaboratively in Problem-based Learning

The project topics for the nine groups were: (1) Nutrition and Hair Growth, (2) Eating Disorders, (3) Betel Nut, (4) Nutrition and Color-blindness, (5) The Effects of Viagra on Impotence, (6) Nutritional Value of Insects, (7) Ginseng, (8) Slimming Centers, and (9) Dentition. Groups 4 and 5 initially had misconceptions that color-blindness and impotence were due to nutritional deficiencies but the teacher allowed them to research the topic to find out whether their conceptions would change in the process of their inquiry. The findings on students' questions raised in collaborative knowledge-building contexts are presented as two assertions below and supported with illustrative examples.

Assertion 1: Students' course of learning and inquiry were driven by their questions. These questions could be classified into four main categories and where productive, guided students to engage in different types of thinking and activities which led to knowledge construction.

What students learnt depended to a large extent, on the kinds of questions that they asked. The four categories of questions were: (a) information-gathering questions arising from students' prior knowledge and which pertained to mainly basic factual information, (b) bridging questions that attempted to find connections between two or more concepts, (c) extension questions which led students to explore beyond the scope of the problem resulting in, for example, creative invention or application of the newly acquired knowledge, and (d) reflective questions that were evaluative and critical, and sometimes contributed to decision-making or change of mindsets. Examples of questions from group 8 will be used as illustration. Group 8's problem on "Slimming Centers" read:

> Miss Piggy was severely overweight. She tried to lose weight by exercising , but it was to no avail. Finally, she decided to seek help at slimming centers and try other means such as taking slimming pills or slimming biscuits. As her good friends, we decided to show her our support and find out more about this slimming method.

The students assumed the role of Miss Piggy's friends. They wanted to compare the advantages and disadvantages of different ways of slimming down such as treatments at slimming centers, exercising, dieting, and taking slimming pills. They began by raising information-gathering questions such as "What are fats?" and "What kind of equipment do slimming centers use?". Their search for answers led them to learn about the composition and storage of fat in adipose tissues of the body. In their quest for answers, they also visited a slimming center, sauna, and gym, interviewed the people working there, and conducted a survey of people's beliefs and experiences with slimming. They found out that slimming treatments offered in the salons included bio body-wrap, aromatic steam treatment, lymphatic drainage, and electrotherapy. Slimming products available in the market included the Osim slim belt, slimming cream and bath gel, slimming pills, slimming biscuits, different kinds of low calorie packaged diets, fat absorbers, and Chinese herbal tea.

Subsequently, in attempting to relate their ideas regarding weight loss and body metabolism, they asked bridging questions such as "Does drinking alcohol contribute to pot bellies?", "How does a sauna help a person to slim down?", "How do fats disappear when one slims down? Where do they go?", and "How do the ingredients found in slimming pills help us to lose weight?". These questions led students to learn about the metabolism of fats in the body, the relationship between calorie intake and the expenditure of energy, and that weight loss is linked to a reduced calorie intake and an increase in metabolic rate. The students also asked themselves "What can we do with the new knowledge that we have learnt?", an extension question. This brought them to an inventive phase where they created a slimming product -- a herbal bag which they named "Slender Teabag" containing dried chrysanthemum flowers and a concoction of Chinese herbs believed to aid weight loss.

During their project presentation, the group reflected on what was the key lesson that they had learnt through working on the project. They also asked reflective questions such as "What are the advantages and disadvantages of the different ways of slimming?" and "What are the side effects of weight loss programs?". They replied that "Although we have seen many effective slimming treatments, we still think that the best way is to stay slim the 'natural' way. The slimming treatments cost too much and also have some side effects." Instead of being convinced by the slimming methods advocated by slimming centres, the students had instead formed strong opinions against the use of these slimming methods, and concluded that sensible eating and regular exercise were still the most effective and economical ways of slimming.

As inquiry is a dynamic and iterative process, the students did not ask these questions in any linear sequence or fixed pattern across these four categories. At times, their search for answers led them back to basic information-gathering questions whenever fundamental but new knowledge gaps had to be filled.

Assertion 2: The ability to ask the "right" questions and the extent to which these questions could be answered, were important in sustaining students' interest in the project.

Not all the questions that students asked were productive in that they led to answers which filled their knowledge gaps. Sometimes, the students found themselves in blind alleys and impasses, making little headway in their search for answers to their questions. If their questions enabled the students to move on to the next stage of their investigation, they were kept motivated and actively involved. However, if students were unable to channel their thinking towards asking productive questions and activity, this could lead to a decline in interest in their project work.

For example, Group 4 which worked on Nutrition and Color-blindness began with questions like "How does nutrition affect color-blindness?", and "Can we improve color-blindness through medication and nutrition?". However, they found little information available in books or the Internet to answer their questions and began to get discouraged. By posing questions such as "What is the cause of color-blindness?" and "Why are some people born color-blind?", they later discovered their earlier misconception and found out that the condition was due to a sex-linked genetic disorder. Despite being unable to find out the answers to their original questions, the students subsequently did ask more questions which eventually led them to research into other areas (viz., cataract, glaucoma, myopia, night blindness, and macular degeneration), opening up a new world of information.

Similarly, Group 5 which wanted to study The Effects of Viagra on Impotence, were also unable to obtain substantial information related to their questions such as "How can food affect one's fertility?" and "What herbs should one eat in order to be fertile?". When they failed to find any link between impotence and nutrition, they continued to ask questions from all different angles and perspectives. The turnaround came about when the students asked questions such as "What are the causes of impotence?" and "What are the remedies?". The answers to these questions led the students to abandon their original assumption of the link between diet and impotence. The students then redirected their questions towards how impotence could be treated and various forms of therapy. They learnt that impotence could be a result of faulty anatomy of the genitals, psychological problems, or the side effects of drugs taken. They also found out that common remedies included the use of vacuum devices, hormonal treatment, and surgery, and that the active chemical in Viagra was sildenafil citrate.

Discussion and Conclusions

Sources of Inspiration and Questions Asked Individually during Problem Identificatoin

The majority of students' questions were inspired by factors external to the school. Also, questions which arose from ideas related to personal experiences and family members' concerns formed a large proportion of the higher-order thinking questions, while questions stemming from ideas related to the school curriculum sought to acquire only basic information. These findings imply that students' experiences outside of school offer rich opportunities in activating their learning, and teachers should tap on this vast potential

wherever possible. Students are sometimes puzzled or intrigued by observations and events in their lives beyond school and have several questions pertaining to these.

Teachers can also capitalize on students' out-of-school experiences by initiating instruction with scenarios and examples taken directly from their students' personal lives. Anchoring instruction around such human stories could bring about a better appreciation of the place of science in contemporary life, and signal to students that the questions and answers that arise in their daily experiences are valued. An understanding of students' sources of inspiration and questions could also provide teachers with a picture of students' preconceived ideas, alternative conceptions, or misconceptions that are related to the topic at hand.

By situating syllabus content in real-life contexts, especially in daily life examples that students can relate to, teachers can build bridges between scientific concepts and real-life experiences, thus mediating between students' everyday world and the world of science. Teachers can also spice up their lessons by infusing students' ideas that deal with such teenage concerns or folklore, which could then spawn further questions and ideas for subsequent investigation and discussion.

Questions Asked Collaboratively during Problem-based Learning
Different types of question (viz., information-gathering, bridging, extension, and reflective) served different functions in students' knowledge construction. Information-gathering questions sought basic or factual information, bridging questions stimulated students to link concepts, extension questions steered students to apply their knowledge or explore beyond, while reflective questions led to evaluative and critical thinking or decision-making. Driven by curiosity, puzzlement, and knowledge gaps, students ask questions which serve to reduce their level of puzzlement. These questions then force students to expand their thinking as well as to generate new questions, new answers, and new ideas. The teacher's role as facilitator would then be to scaffold students' thinking and guide students through both problem-identification and problem-solving by helping them to think of questions from all the above categories.

Although questions which led students to blind alleys seemed unproductive in that the search for answers seemed futile initially, the course of learning and outcome depended on how students responded. When students persevered and continued to pose questions from multiple perspectives, they were able to channel their efforts towards other directions and to arrive at some meaningful product eventually. As asking the "right" kind of questions is important for the success of students' independent learning in PBL, students should be taught and encouraged to ask questions from many different stances, especially when they are stuck in an impasse. The strategy of asking questions as widely and as creatively as possible could lead them out of the cul-de-sac. In connection with this, the suggestions given in Chin, Brown, and Bruce (2002) on how teachers can foster student-generated questions would be relevant here.

Several misconceptions that students had about nutrition-related issues surfaced during the PBL process, through analysis of student's questions. This suggests that teachers can use students' questions to elicit their misconceptions and then deal with them accordingly.

PBL, which involves students crafting their own problems, generating questions, and investigating related learning issues, is an inquiry-based approach to promoting student-centred learning in the classroom. This study has found that in PBL structured around students' questions as anchors, the questions facilitate learning by directing students' inquiry and scaffolding their thinking. Several authors (e.g., Graesser and Person, 1994)) have reported on the paucity of student-generated questions in classroom learning, despite the educational potential of such questions in meaningful learning. This study has shown that PBL can be used to bridge this gap, and mediate between the vision of "question-driven learning" and current practice.

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