PSYCHOLOGY FOR TEACHERS: STUDENTS' APPROACHES TO LEARNING SCIENCE

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Abstract: In this paper, the nature of students' approaches to learning is first described from a general perspective. Different theoretical and psychological perspectives regarding this and the factors influencing the learning approach adopted by students are discussed. Following this, a review of research focusing on students' approaches to learning science is presented. This includes the relationship between students' approaches to learning and science learning outcomes, and a comparison of deep and surface learning approaches in science. Finally, some related issues and implications for curriculum practice in the science classroom are discussed.

Students' Approaches to Learning

Research on approaches to learning derives much from the seminal work of Marton and Saljo (1976) on reading from text using phenomenographic methods, where learning is studied from the perspective of the learner, based on qualitative analysis of interview data and descriptive analyses of differences between the learning behaviors of small numbers of students. On the basis of the students' accounts, these authors distinguished between deep and surface approaches to learning. Although this construct, approach to learning, was originally conceptualized in the context of reading from texts, it has been extended and generalized to other tasks such as writing (e.g., Biggs, 1988) and other content areas (Entwistle and Ramsden, 1983).

The general framework and defining features of the deep and surface approaches have been described by Biggs (1987) and Marton (1983). In essence, the deep approach is associated with intrinsic motivation and interest in the content of the task, a focus on understanding the meaning of the learning material, an attempt to relate parts to each other, new ideas to previous knowledge, and concepts to everyday experiences. There is an internal emphasis where the learner personalizes the task, making it meaningful to his or her own experience and to the real world. In contrast, the surface approach is based on extrinsic or instrumental motivation. The learner who uses a surface approach perceives the task as a demand to be met, tends to memorize discrete facts, reproduces terms and procedures through rote learning, and views a particular task in isolation from other tasks and from real life as a whole.

Theoretical Perspectives

Biggs (1994) refers to four models relating to students' learning approaches which are derived from "personality, information-processing, phenomenographic theories, and systems theories" (p. 318). Studies of learning approaches have mainly been based on the latter two theories, and construe student learning as taking place within the teaching/learning context rather than just within the student, as the former two models appear to assume.

The personal styles model (e.g., Kolb, 1976) focuses on stable, individual traits that are thought to be "in-built features of the individual" (Riding and Cheema, 1991, p. 196), habitually adopted, and to transcend particular learning contexts or content domains. As such, they are typically and more appropriately referred to as a cognitive style or learning style rather than a learning approach. The information-processing model is based on a behaviorial-process orientation and the cognitive and metacognitive strategies that students use when handling tasks (e.g., Weinstein, Schulte, & Palmer, 1987). It is similar to a learning style in that information strategies are conceived as being somewhat independent of context, but differs in that the emphasis here is on strategy use rather than unchanging traits. The phenomenographic model is represented in the work of Marton and Saljo (1976). From this perspective, the learning approach adopted by the learner is seen to be highly dependent on the nature of the task and its context, and how the learner perceives this.

In the systems model (Biggs, 1994), personal traits, contextual factors, level of processing, and quality of outcome are seen as mutually inter-related and "forming an open-ended and recursive system, in which individuals adjust their intentions and processing strategies to their view of the task demands" (p. 320). That is, students enter a learning situation with stable characteristics (e.g., abilities, preferred ways of learning) and adjust their approach to learning according to how the teaching context is structured and the particular teaching demands.

Factors Influencing the Learning Approach Adopted

In an earlier description of the systems model where Biggs refers to it as the 3P (presage, process, product) model of student learning (Biggs, 1987), he describes both personal and situational factors as presage factors that exist prior to and which interact to determine the learning approach adopted in a learning situation. Personal factors include ability, personality, locus of control, cognitive style, motivation, values, attitudes, prior knowledge, conceptions of learning, and general experiences, while situational factors comprise nature of task, time pressures, the context in which it is performed, method of teaching, assessment, and perceptions of institutional requirements. These presage factors effect the quality of performance (product) or learning outcomes via the learning approach (process) adopted. The learning approach comprises the motive for undertaking the task and the congruent strategies used.

Thus, the systems model incorporates the phenomenographic focus on how students tackle a task in relation to its specific demands, the concern with strategies in the information-processing model, as well as the personal traits aspects of the personal styles model. A learning approach from the systems model view differs from information-processing by including motivational and contextual components, and from phenomenography by recognizing the role of personality factors, motives, and preferred ways of learning. Approaches in the phenomenographic sense, while emphasizing the importance of context and the learner's immediate intentions in handling a particular task, pay less attention to the learner's dispositions.

While most authors generally believe that the learning approach adopted is a result of both individual and situational factors, there is less agreement regarding the relative influence of the learning context and predisposed characteristics of the learner. For example, Marton (1983) stresses the overriding importance of the particular context in determining whether a deep or surface approach to learning is used, and emphasizes that the approach to learning should not be seen as a individual characteristic of the student but as a response to a situation. However, Schmeck (1988) believes that students have a predilection to adopt deep or surface approaches that persist over different situations and refer to this consistency as a learning orientation. Biggs (1987) also shares this viewpoint and argues that although students can change their approaches to learning according to the demands of each situation, the extent to which this change occurs is affected by the student's predisposition to change, and which is in turn influenced by personal characteristics such as ability.

Research on Students' Approaches to Learning Science

Most of the earlier research on students' learning approaches was done in domains other than science, with the initial studies focusing on reading from text (Marton and Saljo, 1976) and writing (Biggs, 1988). In the area of science education, the research on learning approaches may be divided into two main categories: (a) those that focus on the relationship between approaches to learning and science performance, and (b) those that attempt to define what is meant by deep versus surface learning in science.

Relationship Between Students' Approaches to Learning and Science Learning Outcomes

Research suggests that a student's learning approach is a factor influencing his or her learning outcome. For example, the study by Cavallo and Schafer (1994) on grade 10 students' understanding of genetics topics showed that the more meaningful the students' learning orientation, the more meaningful the understanding they tended to attain (as measured by the inter-relatedness and complexity of their knowledge exhibited). Using regression analysis, the authors found that meaningful learning orientation was a unique and distinct variable that contributed to students' meaningful understandings of genetics topics beyond that of aptitude and motivation. The students' learning approach was identified by a questionnaire which was based on the original instruments of Entwistle and Ramsden (1983) and Biggs (1987). The degree of meaningful understanding was measured by what the authors called "mental model assessment" where the students had to provide a comprehensive written description of the understanding of meiosis and Punnett-square diagrams. Students who were rated as most meaningful in the learning orientation attained the greatest meaningful understandings of meiosis. Also, with low prior knowledge, meaningful learners apparently attained more meaningful understanding than mid-range or rote learners.

Studies by Hegarty-Hazel and Prosser (1991a, 1991b) on a sample of university students showed that for both student learning in electricity and photosynthesis, deeper and more meaningful strategies were associated with better developed propositional knowledge and more surface strategies with less developed propositional knowledge. The learning strategies that students adopted had a substantial and direct effect on the development of knowledge in their science courses. In these studies, Bigg's (1987) Study Process Questionnaire was used to provide indicators of students' learning approaches. Concept mapping tasks were used as measures of the students' propositional knowledge of electricity and photosynthesis. The concept maps were analyzed on several dimensions pertaining to the extent to which ideas were inter-related (integration), how well more specific concepts were subsumed under more general concepts (differentiation) and the degree to which the propositional statements were correct (articulation of propositional structure). The results showed positive correlations between post-concept-map and deep study strategy variables, and negative correlations between post-concept-map variables and surface study strategy variables. This suggests that deeper and more meaningful strategies are associated with better developed post knowledge and more surface strategies with less developed knowledge. Also, a lack of prior knowledge was associated with the adoption of a more surface learning approach while substantial prior knowledge was related to the adoption of a deeper approach.

One study that has attempted to determine the relationship between students' learning strategies and the change in their conceptual knowledge during a high school chemistry course was reported by BouJaoude (1992). It was found using multiple regression analysis, that the students' learning approach and their performance on a "misunderstandings" pre-test (on concepts related to chemical changes) both accounted for a statistically significant proportion of the variance on their performance on the misunderstandings post-test. In addition, the relatively meaningful learners performed significantly better than the relatively rote learners on the misunderstandings post-test, as determined by an analysis of covariance using scores on the pre-test, an attitude test, and an aptitude test as covariates. Analysis of the differences between students' responses showed that relatively meaningful learners, for the most part, developed more coherent understandings of some of the concepts underlying the questions on the test. These findings suggest that relatively meaningful learners were better able to change their conceptions about chemical change.

These four above-mentioned studies on the learning of science focused on the relationship between students' learning approaches and their science performance, with an emphasis on the quantitative outcome of learning. In summary, the findings show that a deep approach characterized by meaningful learning is associated with more inter-related and better developed propositional knowledge, more coherent understanding of underlying concepts, and fewer misconceptions.

In an attempt to relate students' strategies to a deep or surface approach, Dall'Alba (1986) reported a study which explored the nature of the relation between particular strategies or patterns of strategy application and learning outcomes in an open-ended science problem-solving task where students were required to formulate their own solution method. Ten students aged between 13 and 15 years were engaged in a problem which required them to determine which of three types of sticky tape stuck most strongly to a board. During the activity, the students were encouraged to "think aloud" and each interview was audio-taped. The interview transcripts were used in the identification of learning strategies.

For example, one of the students who was regarded to be using a deep approach and who successfully solved the problem, considered a range of possible steps before deciding on a solution method. She then excluded from her method, those steps which she considered to be unnecessary in solving the problem. Specifically, she considered how she might use the given individual items, then excluded the unnecessary ones. Another student who was also considered to be using a deep approach planned a general procedure prior to looking at the given apparatus. His procedure was based on his recall of a television program which dealt with a similar problem. After planning the general procedure, he planned how he could utilize some of the apparatus provided. He also considered the individual steps in relation to the whole problem. Hence, although learners may adopt the same approach to a task, they can carry it out in distinctly different ways. Students who adopted a surface approach tended to focus on individual steps and failed to relate them to the whole. In some instances, by concentrating on procedures, the students deviated from the given problem. They appeared to lose sight of the way in which the procedures related to the solution of the problem.

Comparison of Deep and Surface Approaches to Learning Science

Entwistle and Ramsden (1983) found that students typically perceived science learning tasks as factual, hierarchical, logical, rule- and procedure-governed, and characterized by a greater consensus regarding content, method, and paradigm. However, arts and social studies tasks were perceived as interpretive, comparative, generalized, and more self-governed. Thus, although the fundamental differences between deep and surface approaches can be applied to many subject areas, what they specifically mean will, to some extent, depend on the subject area or task in question as different subjects and tasks make different demands on the strategies that students use. That is, the meaning of the constructs "deep" and "surface" may be subtly different in different subject areas. Hence, while the meaning of the deep/surface constructs may be fundamentally the same across different subject areas, the application to a particular subject such as science and its associated tasks may be manifested in slightly different ways.

One early study that attempted to explore what is meant by deep and surface learning approaches in science was carried out by Laurillard (1978, cited in Entwistle & Ramsden, 1983) and based solely on self-reports during interviews of university students. It was found that a deep approach was associated with a sense of purpose in carrying out a task, attempts to relate ideas from different topics to the task in hand, and the experience of the physical world to scientific concepts. On the other hand, a surface approach was characterized by an over-concentration and unthinking use of procedures in performing a task, and a focus on memorizing formulas and facts.

A more recent study by Chin (1999a, 1999b) on a sample of Grade 8 students in the U.S. attempted to identify the kinds of learning strategies associated with a deep approach to learning science, as well as compare the differences between a deep and surface approach. In addition to data deriving from interviews and written tasks, the students were also observed performing science hands-on activities during regular science classes. In summary, the strategies associated with a deep learning approach included generating mental images and analogies, hypothesizing, constructing thought experiments and predicting possible outcomes, self-explaining and theorizing, invoking personal experiences and prior knowledge and applying them to new situations, thinking of specific examples, and looking for coherence by seeking patterns and relating different aspects of the task. When students used a deep approach, they ventured their ideas more spontaneously; gave more elaborate explanations which described mechanisms and cause-effect relationships or referred to personal experiences; and asked questions which focused on explanations and causes, predictions, or resolving discrepancies in knowledge, and which had a greater potential to lead to an advancement in conceptual understanding. They also displayed more cognitive appraisal and regulatory control of the learning process through ongoing reflective thinking. In their approach to tasks, they tended to think ahead and predict outcomes, showed a more sophisticated level of observation, engaged in "on-line theorizing" and were more likely to engage in talk at a higher cognitive level beyond the procedural and observational levels that learners using a surface approach typically engaged in. Students using a surface approach gave explanations that were reformulations of the questions, of a "black box" variety which did not refer to a mechanism, or macroscopic descriptions which referred only to what was visible. Their questions also referred to more basic factual or procedural information.

Other salient findings of the study, the details of which are given in Chin and Brown (in press) include the following:

- Using a deep approach can sometimes lead a learner to form idiosyncratic ideas which are scientifically incorrect.
- Even among students who used a deep approach, they showed a tendency to be deep in different ways.
- During group work activities, the roles assumed by the students were found to some extent, to follow their stereotypes even though the students were not assigned by their teacher to any specific roles in their groups.
- Although the students who used more of a deep approach were naturally more inclined than the other students to use deep processing strategies (e.g., predicting, self-explaining), this did not always seem spontaneous but was manifested only upon further probing or prompting during the interviews and when the students were specifically asked to explain a phenomenon.

Discussion and Implications for Curriculum Practice

What implications, then, can be drawn from the above review and discussion regarding students' approaches to learning science? The findings from the work of Cavallo and Schafer (1994), Hegarty-Hazel and Prosser (1991a, 1991b) and BouJaoude (1992) on the relationship between students' learning approaches and their conceptual understanding show that a deep approach characterized by meaningful learning is associated with more coherent understanding and better propositional knowledge, more integrated concepts, and fewer misunderstandings. This is consistent with Ausubel's theory of meaningful understanding (Ausubel, Novak, & Hanesian, 1978). The results of Dall'Alba's (1986) study also indicate that differences in science performance were attributable to learners using different learning strategies associated with a deep or surface approach. Furthermore, although adopting the same approach to a task, learners may carry it out in distinctly different ways. The studies by Chin (1999a, 1999b) identified the learning strategies associated with a deep approach and showed how students adopting deep versus surface learning approaches responded differently to tasks. Thus, the outcomes of science learning is dependent on how students learn, which is in turn dependent on the learning strategies adopted by students and how they approach particular tasks. The work of Novak and Gowin (1984) suggests that students who do not tend to learn meaningfully can learn to do so, and this may help them to develop better conceptual understanding of science topics. Thus, to help students improve their learning in science, teachers could encourage their students to adopt deep processing strategies.

The study by Chin and Brown (in press) also found that using a deep approach could sometimes lead students to form non-canonical ideas. One reason could be that because of their deep thinking, these students do not always simply accept standard scientific answers unthinkingly and can thus generate alternative ideas and mini-theories as they theorize. Thus, it may be that although active on-line theorizing could potentially lead students to generate non-scientific ideas, other deep processing strategies could also help them detect conflicts between the evolving ideas and what is correct. On the whole, this may have a compensatory effect and lead to improved learning in the long run.

The finding that even students who used a deep approach were deep in different ways (e.g., using a theoretical approach vs. drawing upon personal experiences) reflects individual differences even among those considered as deep approach learners. What this suggests is that students may be more prone to deeper thinking in some dimensions and contexts than in others. By being aware of the multidimensionality of this, teachers could help students deepen their thinking starting from contexts and dimensions where they already show some depth. By the same token, when students adopt a surface approach, this can also be manifested in different ways. For example, they could be diligent in following procedures but be externally regulated in being dependent on others for sources for ideas, or they could be apathetic in task engagement, preferring to watch others perform an activity first before trying it out themselves.

Another finding was that the roles assumed by the students during group work followed their stereotypes when the roles adopted were self-selected. This suggests that if students are comfortable with the roles they assume which are in accordance with their natural disposition, personality, and learning approach (e.g., playing a passive role as mainly an onlooker vs. initiating the tasks, leading others in discussion, and dominating most of the thinking), then this state of affairs may reinforce and perpetuate individual differences in students' learning approaches and allow the gap between them to widen even further. Thus, teachers need to think about ways to support students' learning activities (e.g., regarding group composition and roles, instructional design, task structure) without accentuating differences that may disadvantage some students.

The finding that deep thinking processes are sometimes latent even in students who typically use a deep approach and are manifested only under optimal conditions such as through another person's scaffolding, prompting, or probing as a result of the interaction between the students' dispositions and situational circumstances suggests that if left to their own devices, students may sometimes find it difficult to develop deep processing strategies on their own and may not use deep processing strategies as often as teachers would like them to. If deep strategies are considered desirable in facilitating learning, then this suggests that teachers could scaffold students' thinking to encourage their students to adopt deep processing strategies. Activities which involve questioning, predicting, explaining, and theorizing could be used to bolster a discussion and the students could be explicitly required to do these rather than hope that they would just occur spontaneously.

While the above suggestions on requiring students to explicitly ask questions and give explanations may appear promising, there is a caveat. It is a common assumption that if one makes students perform the same kinds of activities, this would mean that they too would use a deep approach. However, this kind of logical reasoning may not always lead to the expected results when applied to human behavior. For example, Marton and Saljo (1976) found that their attempts to induce a deep approach through forcing students to answer certain types of questions while reading text resulted in a "technification" of the learning process. This demand structure of the learning situation led to an extreme form of surface learning instead where students simply complied with the demands without engaging in deep thinking. Also, a study by Arzi and White (1986) found that after students were trained in asking "good" reflective questions in an attempt to actively engage them in thinking, some of the questions that students asked were simply a glib modification of versions of standard question stems which had been introduced to them.

It was pointed out earlier that several factors interact to influence students' adoption of learning strategies and their learning approaches. In designing their lessons, teachers need to bear in mind the effects of these factors on the adoption of deeper strategies. While it is relatively easy to influence students to adopt the surface learning approach, it is substantially more difficult to facilitate the adoption of deeper approaches.

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