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Students' Learning Approaches: What Does Research on Learning Science Tell Us?

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Introduction

Research on students' learning has shown that how they approach their learning influences their learning outcomes and consequently, to some extent, how successful they are in their academic achievement. *Approaches to learning* refers to "the ways in which students go about their academic tasks, thereby affecting the nature of the learning outcome" (Biggs, 1994). A learning approach comprises both the motive for undertaking the task and the strategies used. Learning approaches lie on a continuum from deep to surface (Marton, 1983; Biggs, 1987). A *deep approach* is associated with intrinsic motivation and meaningful learning. In this approach, the learner focuses on understanding the meaning of the learning material and attempts to relate the different parts to each other — the new ideas to previous knowledge, and the concepts to everyday experiences. A *surface approach,* in contrast, is based on extrinsic or instrumental motivation, where the learner perceives the task as a demand to be met and tends to memorise discrete facts, reproducing terms and procedures through rote learning. A surface approach leads to less developed knowledge networks and weaker conceptual understanding (BouJaoude, 1992; Cavallo and Schafer, 1994; Hegarty-Hazel and Prosser, 1991a, 1991b).

Students can be helped to learn better by fostering a deep learning approach. Fostering deep learning, however, requires an understanding of the factors affecting the learning approach that students adopt, as well as the differences in thinking processes and behaviours that students engage in during learning. If teachers know what contributes to deep and meaningful learning — what it is that students do differently during the learning process that leads to different learning outcomes, and what influences such differences in behaviour — they may be better able to tailor their teaching to individual differences in learning needs and thereby encourage deeper thinking in their students.

The purpose of this paper is to (a) discuss some factors that influence students' learning approaches and identify what contributes to deep learning, (b) compare the differences in characteristics associated with deep and surface learning approaches in science, (c) and draw out some implications for instructional practice.

Review

Factors Influencing Students' Approaches to Learning

Because rote learning takes relatively less effort on the part of a learner initially, it is relatively efficient, in that a learner can repeat verbatim some of the concept definitions and propositions presented in the instruction. Thus, early in a learning program, the rate of learning can be faster for rote than meaningful learning. However, because concepts learnt by rote are stored arbitrarily and non-substantively in cognitive structure and are not as well integrated, they are forgotten easily, or are related to other bits of information in inappropriate ways. On the other hand, knowledge learnt meaningfully is retained longer, is better integrated with related concepts, and more readily applied in a wide variety of new problems or contexts. This high transferability of knowledge is necessary for creative thinking. Indeed, only high levels of meaningful learning can lead to creative production (Novak, 1998, p. 20 and pp. 61–62).

Biggs (1987) describes the personal and situational factors associated with a learning approach as *presage factors*. These interact to determine the learning approach adopted in a learning situation. Personal factors include ability, personality, cognitive style, motivation, attitudes, prior knowledge, and conceptions of learning; while situational factors comprise nature of task and the context in which it is performed, time pressures, the method of teaching, assessment, and perceptions of institutional requirements. These presage factors determine the learning approach (process) adopted, which in turn affects the quality of learning outcomes (product). Biggs (1987) calls this the *3P (presage, process, product) model*, or the *systems model* (Biggs, 1994) of student learning.

Three aspects of the model will be discussed here: epistemological beliefs, goal orientation and motivation, and learning strategies.

Epistemological Beliefs

A student's personal epistemology influences his or her conceptions of and approach to learning. Epistemology concerns individuals' beliefs about the structure and origins of knowledge and may be broadly classified as *positivist* or *constructivist*. In a positivist view, the process of knowing is the search for a verifiable truth. The positivist approach views learning as receiving and storing knowledge; it assumes that an already developed body of scientific knowledge exists which can easily be transmitted by the teacher to students through generally passive instructional means. Constructivists, by contrast, see knowledge as being actively constructed by the learner, not passively received or discovered by an objective experimental method.

Research in science education has shown the relationship between students' epistemologies and their approaches to learning science. Students with positivist or empiricist epistemological beliefs tend to be rote learners oriented to grades (Edmondson and Novak, 1993) and to use more rote-like strategies, because they believe science is like a collection of facts (Tsai, 1998). On the other hand, students having constructivist epistemological beliefs engage in more active learning and use more meaningful learning strategies as the primary goal of their understanding of the material.

Students' epistemological beliefs affect not only the learning strategies employed but also their stance toward activities in the classroom (Roth and Roychoudhury, 1993, 1994). For example, students with positivist beliefs about scientific knowledge regard the textbook as a store of knowledge to be memorised and practised. Such students do not try to find things out on their own but rely on peers and teachers to provide them with guidance to get things right. However, those with a more constructivist perspective would use laboratory activities to arrive at new knowledge on their own, through personal involvement. Also, when students view science as dynamic, they are more inclined to seek principles to explain and integrate their diverse ideas and to build more predictive ideas about science (Songer and Linn, 1991).

Just as students' personal epistemologies influence their learning approaches, so do teachers' epistemologies influence their choice of teaching methods (Benson, 1989; Gallagher, 1991; Hashweh, 1996; Tobin and Fraser, 1988). For example, Gallagher (1991) found that teachers with positivist views of science emphasise the "scientific method" and objectivity of scientific knowledge. They tend to portray science as a body of knowledge and try to cover the content in textbooks. On the other hand, Hashweh (1996) reported that teachers who held constructivist views use a richer repertoire of teaching strategies, and use potentially more effective strategies for inducing conceptual change. Since teachers' epistemologies influence how they teach, this also affects how students learn.

Goal Orientation and Motivation

Research shows that students' goal orientations and motivation influence their choice of learning strategies and this, in turn, influences the quality of their cognitive engagement; that is, the degree to which they approach a learning activity purposefully and respond to it thoughtfully. Studies by Lee and Anderson (1993) and Lee and Brophy (1996) showed that motivated students demonstrated high quality of cognitive engagement, while those who were not motivated to learn were likely to adopt strategies for meeting accountability pressures with the least possible effort.

When students pursue learning or task goals, they see learning as an end in itself and seek to understand the task. They are likely to employ deep cognitive and self-regulated strategies, such as integrating information and monitoring comprehension, which result in meaningful learning or conceptual understanding (Meece, Blumenfeld, and Hoyle, 1988). In contrast, students who pursue "performance" or ego goals seek to demonstrate their ability or gain social approval; they tend to use more surface level strategies, such as memorization. Some students pursue work-avoidant goals, seeking to complete their tasks without thinking too hard. This orientation is associated with use of rote-level rather than deep-processing strategies (Nolen, 1988).

Learning Strategies

Students' choice of learning strategies is closely associated with the learning approach that they adopt. When students attempt to learn meaningfully, to relate new and existing knowledge or build internal associations among different concepts in their efforts to understand, they need to use elaboration and integration strategies. Such strategies are most potent in promoting deep learning. When students learn deeply, they also monitor their understanding and reflect on the learning process.

Chin and Brown (2000a) found a number of elaboration and integration strategies associated with a deep learning approach:

(i) visualizing and generating mental images,
(ii) creating analogies to explain scientific phenomena,
(iii) hypothesizing, constructing thought experiments and predicting possible outcomes,
(iv) giving explanations and constructing theories,

(v) invoking personal experiences and prior knowledge, and applying them to new situations, and
(vi) asking questions.

Other metacognitive or comprehension-monitoring strategies included:

(i) self-evaluating and self-questioning,
(ii) defining a problem and establishing the main ideas,
(iii) detecting and self-correcting one's errors,
(iv) attending to contradictory information and alternative ideas, and
(v) considering limitations in one's own or others' ideas and critiquing them.

These different individual strategies interact during deep learning, leading to an overall "depth dynamic". Such strategies are not invoked in surface learning, or they are applied only as isolated responses to stimuli.

Differences Associated with Deep versus Surface Learning Approaches

Do we know what kinds of thinking behaviours are associated with deep and surface approaches to learning science? Chin and Brown (2000b) found differences in five key dimensions: *generative thinking, nature of explanations, asking questions, metacognitive activity, and approach to tasks.*

When students used a deep approach, they displayed a greater degree of "generative thinking". They ventured their ideas more spontaneously, their ideas were more elaborative, and their responses often incorporated examples, self-generated analogies, and daily life experiences. In contrast, students who used a surface approach remained stuck, frequently saying "I don't know", or giving responses that did not directly answer a given question or that were less detailed. They groped around without a sense of directional link between isolated ideas.

The explanations associated with deep learning related to personal experiences in daily life, or described cause-effect relationships and focused on the mechanisms of how things work in the physical world. They tended to be like mini-theories or models which attempted to account for what was not perceptually obvious. In contrast, explanations associated with surface learning tended to be reformulations of the questions, did not explain why or how things happened, or referred only to what is visible.

The questions associated with a deep learning approach tended to be "wonderment" questions, reflecting curiosity, puzzlement, scepticism, or speculation. They focused on explanations, predictions, resolving discrepancies in knowledge, application, and planning. Such questions were more likely to contribute to an advancement in conceptual understanding. On the other hand, questions associated with a surface approach pertained to more basic information. They focused on factual recall, or sought clarification about a given procedure, or asked how a task was to be carried out.

When students used a deep approach, they also displayed more cognitive self-appraisal and regulatory control of the learning process, through ongoing reflective thinking. Such self-monitoring and self-evaluative behaviours were less likely to be associated with a surface learning approach.

In their approach to tasks, students using a deep approach engaged in "on-line theorizing": they spontaneously generated explanations or mini-theories to account for observed phenomena. They also showed a more sophisticated level of observation, going beyond what was visible and obvious to infer patterns and trends. They tended to think ahead and predict outcomes when performing an activity, and were more likely to engage in talk at the conceptual, analytical, and metaconceptual levels. On the other hand, when students adopted a surface approach, they showed a more limited focus during task engagement and noticed mainly gross, macroscopic features. During group discussions, they typically engaged in talk at only the procedural and observational levels.

Implications

The nature of tasks that teachers set and the cognitive demands required of students determine to some extent, the learning approach and learning strategies that students adopt. For example, open-ended, problem-solving activities elicit more and a wider range of higher-order thinking questions and consequently encourage deeper learning, compared to teacher-directed activities where step-by-step activities are given (Chin, Brown, and Bruce, 2002).

While rote learning of information can be faster and result in seemingly more efficient learning and higher achievement scores in the early stages of a learning program, this rate of learning will decline with time (Novak, 1998, p. 62). The learning speed for meaningful leaning is relatively slower initially, but this type of learning better serves the student in the long run as it leads to more coherent, integrated, and substantive knowledge, with greater transferability and capacity for creativity.

In light of the above research findings on students' learning approaches, some implications can be drawn for classroom practice:

Implications

(i) To encourage deep thinking, *teachers should design and present laboratory activities as problems to be solved rather than 'experiments' to be verified according to given instructions.* Also, assessment tasks that require students to synthesise their ideas and apply taught concepts to novel situations encourage deep learning, while those that reward low level rote responses encourage a surface approach to learning.

(ii) The way teachers teach can influence the way students perceive the nature of science and scientific knowledge and consequently, the learning approach that they adopt. Thus, *it is important that teachers have some understanding of constructivist teaching and learning, see it as a plausible and viable alternative to transmissive teaching, and appreciate the usefulness of it.*

(iii) Students' goal orientation and motivation towards science activities are, in some measure, influenced by the teaching method and nature of assessment. *Teachers can encourage meaningful learning by incorporating activities and assessment tasks that capture students' interests and which they find relevant to their personal, daily lives such as the application of science to real-world problems and socio-environmental contexts.*

(iv) If left to their own devices, students may find it difficult to develop deep processing strategies on their own. To encourage deep learning approaches and minimize surface approaches in their students, teachers can devise prompts and scaffolds that attempt to elicit deep thinking processes. *When designing students' tasks, teachers should craft questions that require students to use cognitive and metacognitive strategies.* Such strategies include hypothesizing, predicting outcomes, explaining, theorizing, relating to prior knowledge and applying to new situations, asking questions, and self-evaluating.

(v) The description of differences in the nature of students' explanations and questions could help teachers recognize the depth of thinking (deep vs. surface) displayed by their students. *Students could also be told about the attributes of a "good" explanation and be encouraged to move to a "deeper" level of explanation. Likewise, students could also be taught the differences between "good", thinking questions and the more surface "basic information" questions,* *and be encouraged to ask questions at a deeper level.* Several strategies for encouraging student questioning are given elsewhere (e.g. Chin, 2002).

(vi) To foster deep, meaningful learning and encourage higher levels of generative thinking where students feel free to ask thoughtful questions and contribute ideas, *a warm classroom climate with a low risk of censure, criticism, or ridicule is essential.* Without it, students will not venture beyond lower level transactional or procedural forms (Watts, Gould, and Alsop, 1997).

(vii) *What is important is a superior quality of thinking by students about a topic, not just the number of items correct.* When teachers provide opportunities for students to generate their own hypotheses, explanations, interpretations, and questions, and then recognise each attempt as a valuable contribution, they are encouraging their students to adopt deep thinking processes that lead to meaningful learning.

Conclusion

Students' learning approaches determine, to some extent, the nature of their learning outcomes and academic achievement. If teachers are aware of the various factors contributing to students' learning approaches and the characteristics associated with deep versus surface learning, they can be more perceptive and responsive to their students' learning. They can also design their lessons to encourage students' use of deeper thinking strategies and minimize the use of surface strategies. In this way, their teaching would be better aligned to meet the challenges presented in Singapore's vision of "Thinking Schools, Learning Nation".

References

Benson, G. D. (1989). "Epistemology and science curriculum". *Journal of Curriculum Studies,* **21**(4), 329–344.

Biggs, J. (1987). *Student approaches to learning and studying.* Melbourne: Australian Council for Educational Research.

Biggs, J. (1994). Approaches to learning: Nature and Measurement of, in T. Husen and T. N. Postlethwaite (Eds.), *The International Encyclopedia of Education.* (2nd ed., Vol. 1, pp. 319–322). Oxford: Pergamon Press.

BouJaoude, S. B. (1992). "The relationship between students' learning strategies and the change in their misunderstandings during a high school chemistry course." *Journal of Research in Science Teaching*, **29**(7), 689–699.

Cavallo, A. M. N. & Schafer, L. E. (1994). "Relationships between students' meaningful learning orientation and their understanding of genetics topics." *Journal of Research in Science Teaching*, **31**(4), 393–418.

Chin, C. (2002). "Student-generated questions: Encouraging inquisitive minds in learning science." *Teaching and Learning*, **23**(1), 59–67.

Chin, C. & Brown, D. E. (2000a). "Learning deeply in science: An analysis and reintegration of deep approaches in two case studies of grade 8 students." *Research in Science Education*, **30**(2), 173–197.

Chin, C. & Brown, D. E. (2000b). "Learning in science: A comparison of deep and surface approaches." *Journal of Research in Science Teaching*, **37**(2), 109–138.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). "Student-generated questions: A meaningful aspect of learning in science." *International Journal of Science Education*, **24**(5), 521–549.

Edmondson, K. M. & Novak, J. D. (1993). "The interplay of scientific epistemological views, learning strategies, and attitudes of college students." *Journal of Research in Science Teaching*, **30**(6), 547–559.

Gallagher, J. J. (1991). "Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science." *Science Education*, **75**(1), 121–133.

Hashweh, M. Z. (1996). "Effects of science teachers' epistemological beliefs in teaching." *Journal of Research in Science Teaching*, **33**(1), 47–63.

Hegarty-Hazel, E. & Prosser, M. (1991a). "Relationship between students' conceptual knowledge and study strategies—part 1: Student learning in physics." *International Journal of Science Education*, **13**(3), 303–312.

Hegarty-Hazel, E. & Prosser, M. (1991b). "Relationship between students' conceptual knowledge and study strategies—part 2: student learning in biology." *International Journal of Science Education*, **13**(4), 421–429.

Lee, O. & Anderson, C. W. (1993). "Task engagement and conceptual change in middle school science classrooms." *American Educational Research Journal*, **30**(3), 586–610.

Lee, O. & Brophy, J. (1996). "Motivational patterns observed in sixth-grade science classrooms." *Journal of Research in Science Teaching*, **33**(3), 303–318.

Marton, F. (1983). "Beyond individual differences." *Educational Psychology*, **3**, 289–303.

Meece, J., Blumenfeld, P. C., & Hoyle, R. (1988). "Students' goal orientations and cognitive engagement in classroom activities." *Journal of Educational Psychology*, **80**, 514–523.

Nolen, S. B. (1988). "Reasons for studying: Motivational orientations and study strategies." *Cognition and Instruction*, **5**, 269–287.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations.* Mahwah, NJ: Lawrence Erlbaum.

Roth, W. M. & Roychoudhury, A. (1993). "The nature of scientific knowledge, knowing and learning: The perspectives of four physics students." *International Journal of Science Education*, **15**(1), 27–44.

Roth, W. M. & Roychoudhury, A. (1994). "Physics students' epistemologies and views about knowing and learning." *Journal of Research in Science Teaching*, **31**(1), 5–30.

Songer, N. B. & Linn, M. C. (1991). "How do students' views of science influence knowledge integration?" *Journal of Research in Science Teaching*, **28**(9), 761–784.

Tobin, K. & Fraser, B. J. (1988). "Investigations of exemplary practice in high school science and mathematics." *Australian Journal of Education*, **32**(1), 75–94.

Tsai, C. C. (1998). "An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders." *Science Education*, **82**(4), 473–489.

Watts, M., Gould, G. & Alsop, S. (1997). "Questions of understanding: Categorising pupils' question in science." *School Science Review*, **79**(286), 57–63.