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Science Curriculum Components Favored by Taiwanese Biology Teachers

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Abstract

The new 1–9 curriculum framework in Taiwan provides a remarkable change from previous frameworks in terms of the coverage of content and the powers of teachers. This study employs a modified repertory grid technique to investigate biology teachers' preferences with regard to six curriculum components. One hundred and eighty-five in-service and pre-service biology teachers were asked to determine which science curriculum components they liked and disliked most of all to include in their biology classes. The data show that the rank order of these science curriculum components, from top to bottom, was as follows: application of science, manipulation skills, scientific concepts, social/ethical issues, problem-solving skills, and the history of science. They also showed that pre-service biology teachers, as compared with in-service biology teachers, favored problem-solving skills significantly more than manipulative skills, while in-service biology teachers, as compared with pre-service biology teachers, favored manipulative skills significantly more than problem-solving skills. Some recommendations for ensuring the successful implementation of the Taiwanese 1–9 curriculum framework are also proposed.

Key Words: curriculum, science education, teacher education

The new 1–9 curriculum framework in Taiwan provides a remarkable change from previous frameworks in terms of the coverage of content and the powers of teachers. However, whether or not the 1–9 curriculum framework can be fully successful may depend on science teachers appreciating the rationale underlying this framework, and on whether they can take advantage of their opportunity to achieve science education for all. This study therefore employs a modified repertory grid technique, originally developed by Kelly (1955), to investigate biology teachers' preferences with regard to six curriculum components.

In Taiwan, there have been five major National Curriculum Frameworks since the end of World War II. Three secondary curriculum frameworks for biology, published by the Ministry of Education of Taiwan (Ministry of Education, 1956, 1972, 1983), are presented in Table 1. A closer look at Table 1 reveals that the 1956 and 1983 curriculum frameworks appear as typical representatives of the two rationales of social reconstruction-relevance and academic rationalism, respectively, as proposed by Eisner and Vallance (1974). The 1972 framework appears to be a transition between them. The orientation of academic rationalism promotes the argumentation that curricula should emphasise the general concepts and criteria of a discipline, while the orientation of social reconstruction-relevance should aim to "seek to develop a bet-

Table 1
Biology Curriculum Framework of 1956, 1972 and 1983 in Taiwan.

Chapter	1956	1972	1983
1	Components of the World	Introduction	Our Environment
2	The Life of Animals and Plants	Basic Structures of Organisms	Methods of Biological Research
3	Beneficial Plants	Animal Physiology	Components and Structure of Organisms
4	Beneficial Animals	Taxonomy of Animals	Nutritive Metabolism
5	Detrimental Animals	Plant Physiology	Circulation and Transport
6	Interesting and Special Animals and Plants	Taxonomy of Plants	Coordination
7	Taxonomy of Animals and Plants	The Relationships between Organisms and the Environment	Homeostasis
8	Important Minerals	Genetics and Breeding	Reproduction
9	The Earth and Evolution	Evolution	Genetics
10	Relationships among the Components of the World	The Relationships between Organisms and Human Life	Evolution
11			The Organisms in the Biosphere
12			Taxonomy of Organisms
13			Organisms and the Environment
14			Humans and the Environment

ter “fit” between the individual and society” (Eisner & Vallance, 1974, p. 11). The distinction between social reconstruction-relevance and academic rationalism can be elaborated by the curriculum’s emphasis, as proposed by Roberts (1982, 1988, 1998). He suggested that “Correct Explanation” or “Structure of Science” could be regarded as orientations of academic rationalism, and that the orientation of “Everyday Applications,” “Self as Explainer,” or “Science, Technology, and Decisions” were of social reconstruction-relevance.

The underlying rationale and proposed content of a science curriculum are usually interrelated, with the rationale influencing the choice of content (Roberts, 1988). Progressive education, as advocated by John Dewey, was formerly the mainstream in schools and emphasised that the science content for learning should carry social or daily relevance (DeBoer, 1991). This was followed by a curriculum reform in the 1960s and early 1970s that constituted a swing toward academic rationalism. Content in science textbooks during the era of curriculum reform in the 1970s consisted almost exclusively of conceptual scientific concepts and their associated descriptions, without any coverage of the applications of science and historical or human materials, which were popular in the science textbooks of the 1940s (Fensham, 1988). Academic rationalism, apparently, has tended to include more conceptual science content and method in the science curriculum, while social reconstruction-relevance has favored content with social relevance, regardless of whether it is conceptual science content or method.

However, the science curriculum reform associated with the rise in academic rationalism of the 1970s has often been accused of proceeding with little social, cultural or political concern (e.g., Hurd, 1970; Apple, 1979; Cobern, 1998). Beginning in the late 1970s, the pendulum seemingly swung toward the camp of social reconstruction-relevance, and scientific literacy came to be proposed as the major goal of science teaching. By the 1990s, the rationale of social reconstruction-relevance appeared more sophisticated and inclusive. By adopting this approach, conceptual science content and methods were taught not just for their own sake, but for their social or daily usefulness (Cuban, 1995; DeBoer, 1991). The term “scientific literacy,” though vague, could have referred to “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Research Council, 1996, p. 22).

The new 1–9 curriculum framework in Taiwan came into effect in September 2002 and will take over all 1–9 grades in 2004. The framework proposes that the content is not to be learnt for its own sake, but for its applicability in life and in order that it can be used to foster students’ abilities for daily life. Consequently, science teaching in this 1–9 curriculum framework no longer emphasises only scientific concepts and methods as did the previous ones. With its broader view of curriculum emphases in relation to science, it now contains six major domains of ability indicators and a scheme structure of content for teaching, in which the latter serves to achieve the former. The six domains are scientific process skills, scientific cognition, the nature of science, scientific attitudes, thinking skills and the application of science

Table 2
Science Curriculum Framework of 2002 in Taiwan.

Theme	Topic
Components and Their Properties of the World	• Environment of the world • Organisms of the world • Components and properties of matter
Action in Nature	• Changes and Balances • Interactions • Structures and Functions
Evolution and Continuity	• Continuity of Life • The History of the Earth
Life and the Environment	• Daily Technology • Environmental Protection
Continuing Development	• Conservation of Ecosystems • Science and Humanity • Creativities and Civilisation

(Ministry of Education, 2001). The scheme structure of the curriculum content for science is given in Table 2. It is thought to be broader and more inclusive in terms of content than those used before, as shown in Table 1. It is therefore worth noting that a number of different kinds of content with a sense of social reconstruction-relevance, such as the application of science, the nature and history of science, and the ethics and value of science, are included under the titles of "Life and the Environment" or "Continuing Development," which were almost entirely absent in the previous curriculum frameworks and which are quite unfamiliar to current science teachers. Compared with the work of DeBoer (1991) on the history of science education in the US, the curriculum development in Taiwan during the last half century appears to have paralleled the curriculum development in the US, although it has been about 10 to 15 years behind.

Sometimes curriculum change is the most likely factor influencing changes in the teaching and learning processes (Hacker & Rowe, 1997). However, without taking present practices into account, a curriculum change could be a nightmare for practitioners (Black, 1996). It is not very surprising that the literature reveals that traditional practices have been significantly robust and have been resistant to the forces for change, just as social controls, cultural myths, organisations and especially teachers' beliefs in the nature of science, learning, and teaching have been (Cronin-Jones, 1991; Hodson, 1987; Olson, 1981; Tobin & McRobbie, 1996, 1997). Of the factors influencing the implementation of the science curriculum, science teachers per se have usually been seen as a major factor in the literature (Duffee & Aikenhead, 1992; Fullan, 1982; Roberts, 1988). However, Gallard and Gallagher (1994) found that, within a highly centralised system, science teachers, with alternative perceptions regarding students and learning, may, in due course, give up their beliefs, even reluctantly, and eventually adopt a style of teaching more in harmony with fulfilling what the national science curriculum deems as being important. On the contrary, in a more flexible system, science teachers can exert their influence to hamper the successful implementation of a curriculum that conflicts with their attitudes or beliefs. As a result, many curriculum implementations have avoided being too specific about some aspects of the project to be implemented (Olson, 1981). Therefore, unless we understand teachers' conceptions of science and teaching, why they hold them, and the constraints they face, the classroom is unlikely to move from reformed curriculum to reformed practice.

Taiwan has had a relatively centralised system in education and the curriculum framework is mandatory for all pre-college public and private schools. For the past ten to fifteen years, and coinciding with the democratic movement in politics and society, there have been growing demands for deregulation in education and increased power among schools and teachers. The 1–9 framework provides schools and teachers with a degree of flexibility to develop their own curricula and learning content based on the guidance of the national curriculum framework and to arrange the allocation of teaching time for learning areas or subjects based on their own particular needs.

The 1–9 curriculum framework is characterised by a redistribution of power, a switch in the goals of education, and an expansion of content in the curriculum. The challenge of new coverage and the power shift in terms of implementing the 1–9 curriculum in Taiwan has already made schools and communities very nervous. While policy-makers have finished their jobs, what is left must certainly be taken over and implemented by school teachers and administrators. This is the right time to understand what is in the mind of science teachers since they now have increasing power to determine the time allocation and content of their science classes.

Method

The subjects in this study consisted of 69 in-service secondary biology teachers, who were at the time attending an in-service summer school at the National Taiwan Normal University (NTNU), and 116 pre-service secondary biology teachers at the same university. NTNU is the major institute for teacher education in Taiwan and its alumni account for more than half of all secondary biology teachers in Taiwan. Therefore, the subjects could be considered representative of secondary biology teachers in Taiwan in general.

The repertory grid technique (Kelly, 1955; Pope & Keen, 1981) has often been employed to investigate teachers' beliefs regarding the nature of science and of

Table 3
Topic Titles Used in the Instrument.

Science curriculum components	Genetics	Circulatory system
Manipulative Skills (MS)	Observation of chromosomes with microscope	Observation of blood capillary with microscope
Problem-Solving Skills (PSS)	Student experiment design: identification of the genotypes of the fruit fly with red-eyed	Student experiment design: identification of the gas breathed out by animals
Scientific Concepts (SC)	Cell division and chromosome	Introduction of blood and lymph
Social/Ethical Issues (SEI)	The effects of the technology of the replica man on society	The disputes over the commerce of organs
Application of Science (AS)	The consultation of genetics and biological technology	Introduction to cardiovascular diseases and ways to prevent them
History of Science (HS)	Introduction to the life and achievements of Mendel	Introduction to the life and achievements of Harvey

teaching (e.g., Lakin & Wellington, 1994; Lin, 1998; Munby, 1982; Olson, 1981). For this study, we modified the ideas of the repertory grid technique by developing a questionnaire to investigate the relative status of six components of the science curriculum held by the subjects. Six science curriculum components were used as the elements in Kelly's repertory grid technique. They were manipulative skills (MS), problem solving skills (PSS), scientific concepts (SC), social/ethical issues (SEI), the application of science (AS), and the history of science (HS). The former three are thought of as being representative of academic rationalism, while the latter three are representative of social reconstruction-relevance. In this study, we coined six corresponding titles of biological topics in two fields, the circulatory system and genetics. The titles are shown in Table 3. The topic titles are familiar to biology teachers because they are often used in textbooks or teaching modules.

Every three of the six titles in each field in Table 3 formed a triad, for example, Cell division and chromosome, The effects of the technology of the replica man on society, and Introduction to the life and achievements of Mendel. A total of 40 triads, 20 for the circulatory system and 20 for genetics, were listed as the questionnaire in the study. The subjects were asked: "If you were fully authorised to determine your teaching materials in your biology class, which one of the three topics would you choose and which one would you omit?" Four classes of pre-service biology teachers and two classes of in-service biology teachers were asked to respond and return the questionnaire immediately after they all finished. A total of 185 in-service and pre-service biology teachers completed the questionnaire in the summer in-service program and during the following fall semester of the year 2000. The numbers of titles chosen and rejected in the questionnaire were counted. The difference between the numbers chosen and rejected stood for a measure of the favor attached to each science curriculum component. The preference scores were adjusted with a mean of 20 for each component. Therefore, any science curriculum component with scores higher than 20 was considered to be preferable to the biology teachers. On the contrary, science curriculum components with scores of less than 20 were considered to be less preferable.

Results and Discussion

A descriptive statistical test was performed on the scores for the six science curriculum components for all the subjects. The rank order of the means of the six science curriculum components, from the highest to the lowest, were as follows: the application of science (mean = 24.08), manipulative skills (mean = 23.76), scientific concepts (mean = 21.59), social/ethical issues (mean = 19.51), problem solving skills (mean = 17.33), and the history of science (mean = 9.57). The three components of academic rationalism, namely, manipulative skills, scientific concepts, and problem solving skills were in the second, third and fifth positions, respectively, while the components of social reconstruction-relevance, namely, the application of science, social/ethical issues, and the history of science, were in the first, fourth and sixth positions. Although the data do not clearly show which rational orientation the teachers preferred, the top three favored components reflected a compromise in terms of the science curriculum. First, they made the content (scientific concepts) and process (manipulative skills) aspects of science, which were hotly debated during the 1970s and 1980s, compatible with each other, showing that biology teachers now consider both of them to be almost equally important. Secondly, the top three components also combined components of academic rationalism (manipulative skills and scientific concepts) with a component of social reconstruction-relevance (the application of science). Besides, Tamir (1988) claimed that, under the Science–Technology–Society movement, many science teachers regarded the application of science as the desirable content in their science class. This is consistent with the data showing the highest status that teachers gave to the application of science.

In addition, biology teachers often use examples of scientific application in order to make teaching interesting and to make scientific concepts more understandable. It would not be very surprising, then, to see the application of science in the top position. We would surmise that biology teachers have mixed rationalism with their practical teaching.

It has been advocated that the humanistic aspect of science be included in science teaching in which science is thought of as one activity of human culture (Hodson, 1988; Wang & Marsh, 2002). The 1–9 curriculum framework in Taiwan also supports this notion in terms of proposing the history of science and social issues as its major content as shown in Table 2. However, it is worth noting that the components of social/ethical issues and the history of science rank at the bottom of teachers' preferences. Many science educators have argued that the history of science can play a critical role in developing a more adequate understanding of the nature of science (Abd-Ei-Khalick & Lederman, 2000; Duschl, 1990; Klopfer, 1969; Matthews, 1994; Monk & Osborne, 1997; Rutherford, 1964; Wandersee, 1992) and fostering problem-solving ability (Lin & Chen, 2002). Likewise, social/ethical issues have been cited as needing attention in science education, especially in view of the sense of emergency in relation to environmental and biotechnological issues. It is argued that students should understand the multiple aspects of science-related social/ethical issues and develop the ability to communicate and judge in a reasonable manner (Allchin, 1999; DeBoer, 1991). Nevertheless, Poole (1995) suggested that appropriate underlying beliefs and values regarding science-related issues might deeply affect students' attitudes toward science and their science learning. It seems that most biology teachers in this study did not fully appreciate the benefit of using the history of science and social/ethical issues, both of which have been proposed in the new curriculum, in science teaching.

A further t-test comparison was made with regard to each science curriculum component between in-service and pre-service biology teachers as shown in Table 4. The table shows that the pre-service mean for MS (21.82) is higher than the mean for PPS (18.83), and that the in-service mean for MS (27.03) is higher than the mean for PPS (14.81), indicating the same general pattern of favoring MS over PSS. However, it is also shown that the pre-service teachers (mean = 18.83) scored higher on PSS than the in-service teachers (mean = 14.81), whereas the in-service teachers (mean = 27.03) scored higher on MS than did the pre-service teachers (mean = 21.82). Both effect sizes are above 0.6.

Problem-solving skills and manipulative skills can be thought of together in the domain of scientific process skills. However, they are different in certain respects. In general, manipulative skills involve more hands-on activities and could be more easily managed in teaching, while scientific processes and problem solving skills involve more abstract reasoning processes, and the teachers, in general, need to expend more effort on these when teaching. Pre-service biology teachers were found to assign more weight to the problem-solving skills than the manipulation skills, but in-service biology teachers preferred the manipulative skills to the problem-solving skills. This is perhaps due to the practical workload that makes in-service teachers prefer the easier tasks associated with manipulation to thinking and cognition.

Table 4
Comparison of Means of Science Curriculum Components by Pre-Service and In-Service Teachers.

Science curriculum components	Career	*N*	Mean	SD	*t*	*p*	Effect size
Manipulative Skills (MS)	In-service	69	27.03	7.96	3.732	0.000	−0.65
	Pre-service	116	21.82	9.83			
Problem-Solving Skills (PSS)	In-service	69	14.81	6.50	−3.096	0.002	0.62
	Pre-service	116	18.83	9.53			
Scientific Concepts (SC)	In-service	69	21.99	9.99	0.429	0.668	−0.06
	Pre-service	116	21.36	9.28			
Social/Ethical Issues (SEI)	In-service	69	19.57	6.99	0.080	0.936	−0.01
	Pre-service	116	19.48	6.67			
Application of Science (AS)	In-service	69	23.10	6.85	−1.318	0.189	0.23
	Pre-service	116	24.66	8.24			
History of Science (HS)	In-service	69	14.23	9.46	1.204	0.230	−0.18
	Pre-service	116	12.48	9.62			

By comparing the patterns of preference, the data in Table 4 also reveal that the means of four of the measures for pre-service teachers are all similar (MS = 21.82, SC = 21.36, SEI = 19.48, and SEI = 18.83), except for the big difference in AS (24.66) and HS (12.48). This indicates that the pre-service teachers may have a more evenly balanced set of curricular preferences compared to the in-service teachers. This finding makes it clear that more effort should be channeled toward in-service teacher education, particularly when a new curriculum is introduced.

Recommendations

The following recommendations are proposed to help successfully implement the Taiwanese 1–9 curriculum framework. It is suggested that in-service teacher education provide science teachers with opportunities to master the rationale underlying the new curricula, and not just more advanced scientific concepts. However, the latter often accounts for the major part of in-service teacher education. Besides, in-service teacher education should place more emphasis on the teachers' exposure to the history of science and the social/ethical issues of science, which make the new 1–9 curriculum unique to the previous curriculum framework. Teachers should also be encouraged to become familiar with the dynamics of the history of science and develop their science teaching based on social/ethical issues. Conflicting curriculum ideas should be introduced and discussed in both in-service and pre-service teacher education to prevent the views that teachers hold with regard to the science curriculum from being too narrowly focused. The modified repertory grid technique used in this study may serve as an instruction tool to elicit personal preferences for curriculum components, and therefore science teachers should be given enough time to discuss the reasons why they like or dislike the components. This could cause them reflect on their own beliefs and to better understand the sometimes divergent beliefs of others.

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References

Abd-Ei-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057–1095.

Allchin, D. (1999). Values in science: An educational perspective. *Science Education, 8*(1), 1–12.

Apple, M. (1979). *Ideology and curriculum*. London: Routledge & Kegan Paul.

Black, P. (1996). Curriculum change: Dream or nightmare? *Education in Science, 9* (June), 8–9.

Cobern, W. W. (1998). Science and a social constructivist view of science education. In W. W. Cobern (Ed.), *Socio-cultural perspectives on science education: An international dialogue*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*(3), 235–250.

Cuban, L. (1995). The hidden variable: How organizations influence teacher responses to secondary science curriculum reform. *Theory into Practice, 34*(1), 4–11.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York: Teachers College Press.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76*(5), 493–506.

Duschl, R. A. (1990). *Restructuring science education*. New York: Teachers College Press.

Eisner, E. W., & Vallance, E. (Eds.). (1974). *Conflicting conceptions of curriculum*. Berkeley, CA: McCutchan.

Fensham, P. (1988). Familiar but different: Some dilemmas and new direction in science education. In P. Fensham (Ed.), *Development and dilemmas in science education*. London: The Falmer Press.

Fullan, M. (1982). *The meaning of educational change*. Toronto, Canada: OISE.

Gallard, A. J., & Gallagher, J. J. (1994). A case study of a national science curriculum and teacher conflict. *International Journal of Science Education, 16*(6), 639–648.

Hacker, R. G., & Rowe, M. R. (1997). The impact of a national curriculum development of teaching and learning behavior. *International Journal of Science Education, 19*(9), 997–1004.

Hodson, D. (1987). Social control as a factor in science curriculum change. *International Journal of Science Education, 9*(5), 529–540.

Hodson, D. (1988). Toward a philosophically more valid science curriculum. *Science Education, 72*(1), 19–40.

Hurd, P. D. (1970). *New directions in teaching secondary school science*. Chicago: Rand McNally.

Kelly, G. A. (1955). *The psychology of personal construct xxxx*. New York: Norton.

Klopfer, L. E. (1969). The teaching of science and the history of science. *Journal of Research in Science Teaching, 6*, 87–95.

Lakin, S., & Wellington, F. (1994). Who will teach the 'nature of science'?: Teachers' views of science and their implications for science education. *International Journal of Science Education, 16*(2), 175–190.

Lin, C. Y. (1998). A case study of teacher's views of science. *Chinese Journal of Science Education, 6*(2), 113–128 (in Chinese).

Lin, H.-S., & Chen, C.-C. (2002). Using the history of science to promote students' problem-solving ability. *International Journal of Science Education, 24*(5), 453–464.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.

Ministry of Education. (1956). *Standards of secondary curriculum (for Junior High Schools)* (in Chinese). Taipei, Taiwan: Cheng Chung Book Company.

Ministry of Education. (1972). *Standards of secondary curriculum (for Junior High Schools)* (in Chinese). Taipei, Taiwan: Cheng Chung Book Company.

Ministry of Education. (1983). *Standards of secondary curriculum (for Junior High Schools)* (in Chinese). Taipei, Taiwan: Cheng Chung Book Company.

Ministry of Education. (2001). *Structure of elementary and secondary education (for Elementary and Junior High Schools)* (in Chinese). Taipei, Taiwan: Ministry of Education.

Monk, M., & Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: A model for development of the pedagogy. *Science Education, 81*, 405–424.

Munby, H. (1982). The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. *Instructional Science, 11*, 201–225.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Olson, J. (1981). Teacher influence in the classroom: A context for understanding curriculum translation. *Instructional Science, 10*, 259–275.

Poole, M. (1995). *Beliefs and values in science education*. Buckingham, UK: Open University Press.

Pope, M. L., & Keen, T. R. (1981). *Personal construct psychology and education*. London: Academic Press.

Roberts, D. A. (1982). Developing the concept of "curriculum emphasis" in science education. *Science Education, 66*(2), 243–260.

Roberts, D. A. (1988). What counts in science education? In P. Fensham (Ed.), *Development and dilemmas in science education*. New York: Falmer Press.

Roberts, D. A. (1998). Analyzing school science courses: The concept of companion meaning. In R. A. Roberts & L. Ostman (Eds.), *Problems of meaning in science curriculum*. New York: Teacher College Press.

Rutherford, J. F. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching, 2*(2), 80–84.

Tamir, P. (1988). The relationship between cognitive preferences, student background and achievement in science. *Journal of Research in Science Teaching, 25*(3), 201–216.

Tobin, K., & McRobbie, C. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education, 80*(2), 223–241.

Tobin, K., & McRobbie, C. (1997). Belief about nature of science and the enacted science curriculum. *Science and Education, 6*, 355–377.

Wandersee, J. H. (1992). The historicality of cognition: Implications for science education research. *Journal of Research in Science Teaching, 29*(4), 423–434.

Wang, H., & Marsh, D. D. (2002). Science instruction with a humanistic twist: Teacher' perception and practice in using history of science in their classrooms. *Science and Education, 11*(2), 169–189.