Research in Science Education, 2000, 30(4), 357-375

Science Teachers' Beliefs about Curriculum Design

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Abstract

Teacher beliefs about curriculum design affect the quality of science education in schools, but science researchers know little about the interrelation of beliefs about alternative curriculum designs. This article describes a quantitative study of secondary science teachers' beliefs about curriculum design. A 33-item Science Curriculum Orientation Inventory (SCOI) was developed to measure five distinct orientations to curriculum: academic, cognitive processes, society-centred, humanistic, and technological. Data were collected from 810 integrated science, chemistry, physics, and biology teachers in Hong Kong. A confirmatory factor analysis of teacher responses to the SCOI indicated that science teachers' beliefs about curriculum design had a hierarchical structure; the five distinct curriculum orientations were positively correlated, forming a second-order curriculum meta-orientation. Physics teachers were less society-oriented than biology, integrated science and chemistry teachers, and integrated science teachers were more humanistic than physics teachers. Although science teachers' beliefs about any of the five alternative curriculum designs did not vary with their teaching experience, the difference between beliefs about the cognitive processes orientation and the humanistic orientation increased when teachers had gained more teaching experience. Implications of these findings are discussed.

In recent years, increasing attention has been paid by science researchers to different aspects of teacher beliefs about science, such as beliefs about the nature of science (Lederman, 1992; Tobin & McRobbie, 1997), beliefs about teaching and learning of science (Aguirre, Haggerty, & Linder, 1990; Hewson, Kerby, & Cook, 1995), and beliefs about science education goals (Berkheimer & Lott, 1984; McIntosh & Zeidler, 1988). Surprisingly, however, researchers have paid scant attention to examining specifically teachers' beliefs about alternative designs of a science curriculum. Little is known about this important teacher belief system even though researchers have repeatedly argued that teacher beliefs are an important factor affecting the quality of science education in schools.

According to Ornstein (1982), the most fundamental concern of schooling is curriculum. Teacher beliefs about curriculum design may be defined as a set of value premises from which decisions about curriculum objectives, content, organisation, teaching strategies, learning activities and instructional assessment are made. The close relationship between the beliefs of teachers, their teaching behaviours, and their learning goals for students is well documented in the literature (see, for example, Brickhouse, 1990; Cronin-Jones, 1991; Lumpe, Haney, & Czerniak, 1998). Of course, the impact of beliefs on teachers' actions is inevitably mediated by numerous contextual variables (Lederman & Zeidler, 1987), as well as other teacher belief systems (Tobin & McRobbie, 1997). Thus, science teachers with differing beliefs about curriculum design may exhibit similar classroom behaviours as a consequence of contextual constraints and demands. However, if a science teacher does not believe that a particular curriculum design is valuable, he or she will not implement it voluntarily. The teacher may even alter the intended curriculum to make it more congruent with his or her own belief system and classroom context. Hence, if educators want to improve science education in schools, research on science teachers' beliefs about curriculum design is essential.

It is unfortunate that no consensus exists concerning the ideal design of a secondary school science curriculum. This is not surprising because curriculum is a complex human construct. Nonetheless, curriculum specialists (e.g., Eisner & Vallance, 1974; McNeil, 1996; Miller, 1983) have identified several orientations to curriculum (also referred to as curriculum conceptions, perspectives or ideologies), which appear to be largely applicable to science education. For example, McNeil (1996) identified four different curriculum orientations: academic, social reconstructionist, humanistic, and technological. However, specific curriculum orientations, such as those suggested by McNeil, do not exist independently; they cluster together to form a single curriculum meta-orientation (Miller, 1983). Although the meta-orientation construct is potentially a lot more informative and interesting than the specific curriculum orientations, only recently have efforts been made by researchers to measure it empirically.

Using McNeil's (1996) four curriculum orientations as an example, Cheung (2000) hypothesised a hierarchical model that consisted of four first-order factors and one second-order factor. The first-order factors represented McNeil's four separate curriculum orientations: academic, social reconstructionist, humanistic, and technological. The second-order factor denoted the meta-orientation construct. Based on his hierarchical model, Cheung (2000) designed a 32-item curriculum orientation inventory to measure primary school teachers' beliefs about McNeil's four specific curriculum orientations. Hierarchical confirmatory factor analysis of the teacher data revealed that the four orientations were positively correlated and each orientation was a function of the meta-orientation.

Recently, research by Cheung and Ng (submitted) has reconfirmed the clustering property of teacher beliefs. They refined and shortened Cheung's (2000) instrument to form a 28-item curriculum orientation inventory and measured 915 teachers' beliefs about the four curriculum orientations hypothesised by McNeil (1996). Through hierarchical confirmatory factor analysis, they found that a curriculum meta-orientation construct subsumed McNeil's four specific curriculum orientations and explained 97.9% of the covariances among them. Their sample included 465 preservice primary school teachers, 363 inservice primary school teachers and 87 inservice secondary school teachers, but there was no differentiation based upon specific academic disciplines. We are not aware of the existence of similar studies that have measured teachers' beliefs about alternative designs of a science curriculum. The purpose of the present study was to further Cheung and Ng's (submitted) work by adapting their inventory and testing a hypothesised hierarchical model of teacher beliefs with a sample of science teachers in Hong Kong. After an extensive review of both curriculum literature and science literature, we found five distinct orientations to curriculum, which appeared to be relevant to secondary school science. The present study was guided by the following four major research questions:

1. Is there empirical evidence of the existence of a curriculum meta-orientation construct in the science teachers' belief system?
2. What are the relations among the five specific curriculum orientations in the science teachers' belief system?
3. Do science teachers in different academic disciplines differ in their beliefs about curriculum design?
4. Do science teachers' beliefs about curriculum design vary with their teaching experience?

The next section will describe in greater detail the characteristics of each of the five curriculum orientations. It is anticipated that the results of this study will provide valuable information regarding the belief system of science teachers' orientations to curriculum. Such information will be useful to plan inservice training for teachers and to formulate implementation efforts for new science curricula.

Major Orientations to Science Curriculum

Curriculum design is a complex process of conceptualising and organising the various components of curriculum into a coherent system. Based on an extensive review of the research literature on science goals, content, teaching, and learning (e.g., Berkheimer & Lott, 1984; Bybee & DeBoer, 1994; Harms & Yager, 1981; Smith & Neale, 1989; Watts & Bentley, 1994; Yager & Penick, 1988), as well as research literature on curriculum orientations (e.g., Eisner & Vallance, 1974; Klein, 1986; McNeil, 1996; Miller, 1983; Ornstein, 1982), five dominant and distinctive orientations to science curriculum were provisionally identified. The salient features of these five curriculum orientations are summarised in Figure 1. The five orientations represent different value positions, providing alternative prescriptions for the intent, content, organisation, teaching methods, learning activities, and instructional assessment of a science curriculum. The key assumption embedded within each orientation is also shown.

It is important to note that most of the science curricula that have been designed for use in schools reflect one or more of the five curriculum orientations in different degrees. "Pure" forms are seldom found. These orientations are presented in their pure form in Figure 1 for purposes of clarity only. Furthermore, the five curriculum orientations are not exhaustive. A vocational orientation, for example, was deliberately not included because it is not relevant to secondary school science in Hong Kong. Various forms of science curriculum have emerged from such countries as the USA, UK, and Australia. These five curriculum orientations, although not exhaustive, also appeared to adequately discriminate among the major curricular emphases in a variety of science curricula designed in the 1990s. Owing to limitation of space, we cannot describe all the five curriculum orientations in detail here, but a summary of each orientation is given below.

Academic Curriculum

This is the oldest and most widely used curriculum orientation in secondary school science. Advocates of this orientation believe that science is discipline knowledge and content is more important than process. The science curriculum aims at developing students' rational thinking through the study of various science disciplines such as physics, chemistry, and biology. Every science discipline emphasises rigorous intellectual training. Students are expected to think like professional physicists, chemists, or biologists. The significant intellectual achievements of great scientists are treated like the grammar and syntax of the scientific disciplines and thus are selected as the essential content of school science. Traditional topics are taught at the secondary level, and students are required to understand important scientific laws and theories. The secondary 4-5 physics curriculum in Hong Kóng, for example, is entirely devoted to the following six theoretical topics: optics; heat; mechanics; waves; electricity, magnetism and electronics; and atomic physics (Curriculum Development Council, 1993). For each science discipline, the curriculum content is organised on the basis of the logical relationships between scientific concepts. Hence, chemistry teaching, for example, always starts with atomic structure, goes on discussing the periodic table, chemical bonding, and so forth. In the academic orientation, students usually play a passive role in their learning process. Traditional assessment methods, such as multiple-choice questions and short essays, are popular, and the assessment results are mainly used for judging whether individual students are allowed to pursue more advanced study of science.

Orientation/ Assumption	Curriculum intent	Curriculum Content	Curriculum Organisation	Teaching-learning strategy	Assessment
Academic Curriculum Science is discipline knowledge.	Understand science subject matter. Prepare students for advanced study of science. Focus on cognitive learning objectives.	Factual and theoretical knowledge that reflects the structure of a science discipline such as chemistry, biology, and physics.	The logical structure of a science discipline. Science concepts as the curriculum organiser.	Didactic. Students listen to teacher talk, read text, memorise laws and formulae, answer factual questions, watch demonstrations, and practice laboratory skills.	Students' mastery of scientific knowledge.
Cognitive Processes Curriculum Science is a process of inquiry.	Teach students how to learn science. Develop essential inquiry skills.	Scientific methods. Science process skills such as observing, hypothesising, and measuring. General inquiry processes such as problem solving, use of evidence, and analytical reasoning.	Process-led modules.	Laboratory-centred, experimental, process approach. Investigations and simulated research activities. Students learn scientific concepts by discovery.	Students' acquisition of science process skills. Correct use of scientific methods.
Society-centred Curriculum Science is a tool for improving our society.	Help students to become socially responsible citizens who contribute to the development of society. Understand science-related societal issues.	Science-based real-world problems such as genetic engineering, ozone depletion and energy shortage. Emphasise applications of science to societal problems, environmental concepts, ethics, values, decision making, multidisciplinary studies, and careers in scientific fields.	Contemporary societal issues as the curriculum organiser.	An issue-based approach. Action oriented. Multidisciplinary approach. Cooperative activities. Investigations to find out the interconnectedness of events, people and scientific phenomena. Decision-making exercises involving scientific knowledge in a social context. Use of community resources.	The effectiveness of students to use scientific knowledge to interpret societal problems. Ability to make well-reasoned decisions. Recognise the limited role of scientific knowledge in making decisions about societal matters.
Humanistic Curriculum Science is a human form of knowledge and a tool for personal development	Prepare students to utilise science for improving their own lives and for coping with an increasingly technological world. Understand the human nature of science. Integration of affective, cognitive and psychomotor objectives.	Select topics that students enjoy. Scientific knowledge that is seen as useful in everyday life. Applied science topics such as food chemistry. History of science. Implications of scientific advances for individuals.	Student needs and interests as the curriculum organiser. A flexible framework that allows individual students to select the order of learning.	Student-centred. Classroom as a joyful and facilitating environment. A constructivist view of learning. Contextual learning and storyline approach. Use of illustrations and explanations that involve feeling and emotion. Narrative lab reports.	Students' personal satisfaction, self-confidence, moral character and intellectual growth. Students' abilities to use science experiences to interpret and solve personal problems.
Technological Curriculum Technology is a connector between science and society.	Understand the technological aspects of science. Develop abilities of technological design and of locating and analysing technology-related information.	Select contents based on the predetermined objectives. Contents focus on scientific knowledge in a technological context, technological designs, careers in technology, and the effects of technology on society.	The logical order of learning objectives as the curriculum organiser.	Student learning must occur in systematic ways. Use of programmed instruction, mastery learning and instructional technologies such as computer, film, television and lab equipment.	Students' abilities to apply scientific knowledge to the complex technological aspects of everyday life. Competence in handling information technology.

Figure 1. Orientations to secondary science curriculum

Cognitive Processes Curriculum

Unlike the academic orientation, this orientation emphasises process rather than curriculum content. It is based on an inductivist philosophy and stresses the importance of training students in scientific inquiry. The cognitive process enthusiasts believe that there is a so-called scientific method and secondary school students best learn science by behaving as professional scientists, engaging in hands-on laboratory work. Students act as problem-solving scientists and are expected to acquire transferable scientific process skills such as defining problems, making observations, forming hypotheses, controlling variables, performing experiments, and analysing data. In addition, students are required to understand the nature of scientific inquiry and essential procedural concepts such as reliability and validity. They must also master some general inquiry processes such as use of evidence, logical and analytical reasoning, and decision making. Because teachers have to teach the processes of science overtly, science teaching must take place in a laboratory and provide students with opportunities to participate in actual or simulated scientific investigations. Students' performance in laboratory work is usually assessed by teacher observations, practical tests, or written reports. Examples of a process-based science curriculum include the *Warwick Process Science* (Screen, 1986) and *Science – A Process Approach* (American Association for the Advancement of Science (AAAS), 1970).

Society-Centred Curriculum

This orientation views the school science curriculum as a vehicle for facilitating social change. Advocates of society-centred curriculum believe that school science has meaning only in a social context (Carin, 1971). The curriculum content is typified by contentious, science-related societal issues such as genetic manipulation, use of food additive, acid rain, animal transplants, fertility treatments, nuclear energy, water pollution, worldwide starvation, safety of herbicides, effects of tobacco, and population growth. Students are provided with learning opportunities to critically analyse these societal issues, weigh alternatives, and make rational decisions. They not only study the social and economic issues arising from the applications of scientific knowledge, but also need to understand how society has affected the developments of science. The curricular emphasis is on group experiences and development of students' critical consciousness and sense of social responsibility. An issues approach is recommended (Hofstein & Yager, 1982). The project *Chemistry in the Community* (American Chemical Society, 1998) is a good example of a society-centred curriculum; real-life chemically related societal issues, such as water quality, conservation of chemical resources and global warming, serve as the organisers for the chemistry curriculum and its sequence.

Humanistic Curriculum

This orientation to curriculum is based on humanistic psychology (Bybee & Welch, 1972; Rutherford, 1972). The major premise of the humanistic orientation is that students should be the crucial source of all science curricula. Proponents of this student-centred approach to curriculum design are self-actualisers who believe that the function of the school science curriculum is to provide each individual student with intrinsically rewarding experiences that contribute to personal liberation and development (McNeil, 1996; Moheno, 1993). The curriculum helps students realise the important role science plays in their personal lives and attempts to integrate their affective domain (emotions, attitudes, values) with the cognitive domain (intellectual knowledge and abilities). The curriculum content emphasises the needs, interests and emotions of students so that they are better equipped to take decisions about science-related matters that affect their personal or economic well-being. Topics focus on things that are seen as useful in everyday living, such as electricity in the home, disease prevention, and food hygiene. Humanistic science teachers pay attention to students' prior knowledge and try to present materials imaginatively to facilitate student learning. They like to use a historical approach to science teaching, popular science stories, and context-based learning activities (Stinner, 1995), as well as anthropomorphic and animistic explanations (Watts & Bentley, 1994). Alternative assessment methods, such as portfolio and direct observation, are preferred to traditional objective tests. Humanistic science educators believe that, in addition to students' intellectual growth, their personal satisfaction and appreciation of the role of human factor in scientific development should also be assessed.

Technological Curriculum

Supporters of this orientation believe that technology, such as medicine, transport, building, armament and communication, should serve as a connector between science and society. Science is the knowledge base for technology, but technology provides tools and techniques for science. Because science and technology cannot exist independently, students best learn science through teaching of scientific concepts in a technological context (Dreyfus, 1987). Thus, the technological orientation is characterised by an emphasis on applications of science in various technologies and industries. For example, biology students should be able to describe cloning methods and their use in agriculture. Furthermore, students are expected to develop abilities of technological design and to become competent users of information technology. This orientation to curriculum has been heavily influenced by behaviourism (Eisner & Vallance, 1974; McNeil, 1996). Curriculum designers stress systematic planning and efficiency in learning. They focus on finding efficient means to a set of predetermined learning objectives. All the intended learning objectives must be written in operational terms. The organisation of curriculum content is governed by the logical sequence of the objectives. Technological science curricula recommend teachers to use teaching strategies such as programmed instruction, computer assisted instruction and mastery learning (Good & Berger, 1998; Marsh & Kumar, 1992; McNeil, 1996). Traditional objective tests are often used to assess student performance.

Method

Development of Instrument

The salient features of the five curriculum orientations shown in Figure 1 constituted the conceptual framework for constructing a Science Curriculum Orientation Inventory (SCOI). For each curriculum orientation, items were designed to measure its important aspects such as assumptions, intent, content, and organisation. Items from Cheung and Ng's (submitted) inventory were adapted but new items were also constructed to measure unique features of science curricula. Each item was selected for its ability to be distinguished from the other four orientations. For example, the item "Science curriculum should provide students with opportunities to do laboratory work" is important but was not included because more than one orientation supports this kind of curriculum design. In order to encourage science teachers to respond to all items, the SCOI was limited to two pages. With severe length constraints, not more than seven items were designed to measure each orientation, forming a subscale in the SCOI. All items were written in Chinese and positively phrased. Before the SCOI was finalised, the content validity for all the 35 items was reviewed by six academics. They all held a PhD in curriculum studies or science education. A six-point scale (1 = poorly represents, to 6 = strongly represents) was used to evaluate the content representativeness of the items. A minimum value of 4.0 was used as the decision rule for judging representativeness to be acceptable. It was found that the means of the 35 items ranged from 3.3 to 6.0. Only two items had a mean less than 4.0 but both were associated with the humanistic orientation. The wording of these two items was revised in the light of reviewers' feedback, and two new items were also added to measure the humanistic orientation. Furthermore, one item was deleted from each of the other four orientations in order to leave a space for a few items that collected teachers' demographic information. The 33 SCOI items were randomly arranged in the SCOI and some of them have been translated into English for reader information (see Appendix).

Data Collection and Data Analysis

The SCOI items were trialed on an opportunity sample of 12 teachers of secondary science in 1999 and ascertained their clarity. Each item was on an eight-point bipolar rating scale (1 = strongly disagree and 8 = strongly agree). There are about 450 secondary schools in Hong Kong. In the final survey, four copies of the SCOI were sent to every school, inviting the department heads of chemistry, biology, physics, and integrated science to answer the SCOI. The SCOI was also administered to a convenience sample of about 300 science teachers who attended seminars in the first author's university. All participation in the survey was voluntary and no incentives were offered. Completed inventories were returned by a total of 810 teachers; 105 were integrated science teachers, 203 physics, 181 chemistry, 288 biology, and 33 did not report their academic disciplines.

Using the SPSS program, the reliability of teacher responses to individual items and to the five subscales was examined on the basis of item-total correlations and Cronbach's alphas, respectively. Only those items with an item-total correlation greater than .4 were retained. A one-way within-subjects analysis of variance (ANOVA) was then conducted to examine whether the means on the five subscales were statistically different.

To answer the first and second research questions, all the retained items were subjected to hierarchical confirmatory factor analysis (HCFA) using the LISREL program (Joreskog & Sorbom, 1996). A detailed description of HCFA is beyond the scope of this article and is available elsewhere (Cheung, 2000). The LISREL notation is used to depict the hypothesised hierarchical model in Figure 2 (ignoring the values of the parameter estimates for now). The five first-order factors represent the five specific curriculum orientations described in Figure 1. Since teacher belief about curriculum design is a construct that cannot be directly or exactly measured, each first-order factor denotes a latent variable. In the SCOI, items were constructed to indirectly measure each orientation. For example, six items are shown as indicators of the academic orientation in Figure 2 (i.e., items Q7, Q9, Q14, Q20, Q24 and Q30). The academic orientation was hypothesised to influence each of these six items, as represented by the first-order factor loadings (λ). Errors of measurement (ε) are also shown for these six items. This hypothesised model was very restrictive because each of the SCOI items was allowed to load on only one first-order factor (i.e., the curriculum orientation that the item was constructed to measure), and the errors of measurement associated with all items were posited to be uncorrelated. The second-order factor in Figure 2 denotes the curriculum meta-orientation construct. It was postulated to influence all the five first-order factors. Second-order factor loadings (γ) represented the values of these influences. The errors of prediction of the five first-order factors from the second-order factor were represented by error terms ζ.

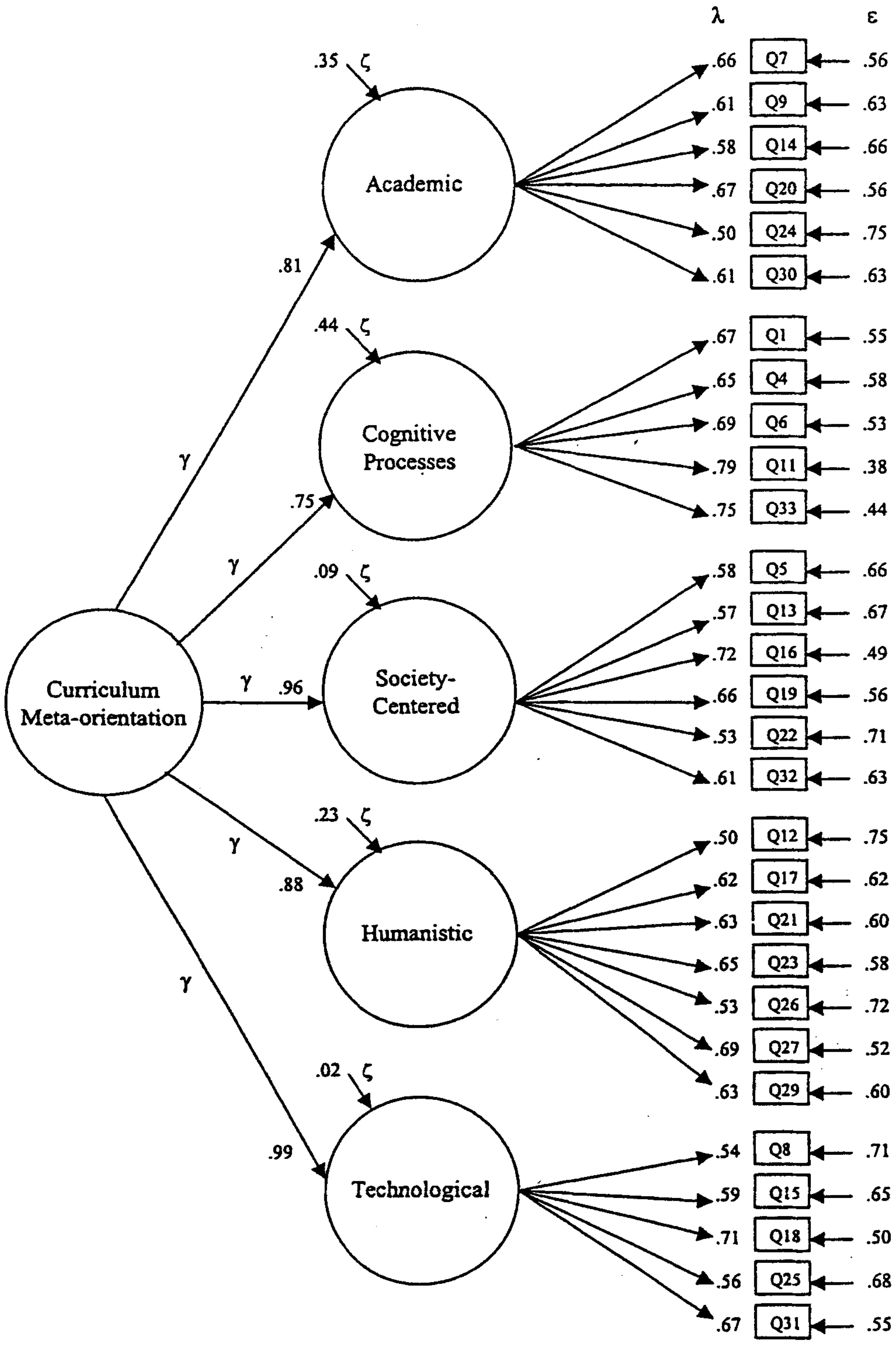

Figure 2: A hierarchical model of science teachers' orientations to curriculum.

HCFA can estimate the unknown values of first-order factor loadings, second-order factor loadings, error terms, and covariances (or correlations, if variables are standardised) among the first-order factors in a single analysis. In the present study, HCFA was performed by the LISREL program using maximum likelihood estimates derived from a covariance matrix based on listwise deletion for missing data. The ability of the hypothesised model to fit teacher responses to the SCOI items was judged by the values of overall model fit indices such as the goodness-of-fit index. In order to assess the ability of the second-order factor to explain the covariation among the five first-order factors, Marsh and Hocevar's (1985) target coefficient was computed, which is equal to the ratio of the chi-square of the first-order correlated-five-factor model to the chi-square of the hypothesised hierarchical model. Target coefficient has a maximum of one, implying that all the covariances among the first-order factors are explained by the second-order factor. With the aid of target coefficient and other overall model fit indices, the goodness-of-fit due to the second-order structure can be separated from that due to the first-order measurement model.

To answer the third and fourth research questions, a two-way multivariate analysis of variance (MANOVA) was performed by the SPSS program to evaluate the effects of teachers' academic disciplines and teaching experience on their beliefs about curriculum design. If the MANOVA tests indicated that there were statistically significant effects, then ANOVAs on each subscale scores were conducted as follow-up tests, using the Bonferroni method to control for Type I error across the tests. Multiple pairwise comparisons were also performed if required.

Results and Discussion

Reliability Tests and Descriptive Statistics

Reliability tests indicated that 4 of the 33 SCOI items had an item-total correlation less than .4 and thus were discarded. Table 1 displays the remaining 29 items. The item-total correlations of these items ranged from .40 to .71 and the Cronbach's alphas of the five subscales varied from .74 to .83, giving support for the reliability of teacher data. Because the reliability of the SCOI is only moderate, further research is planned to improve the instrument by refining the wording of some items.

The means and standard deviations of individual SCOI items are also shown in Table 1. The means varied between 4.87 and 6.81 out of a maximum of 8, indicating that science teachers generally valued all the five seemingly antagonistic curriculum orientations. The standard deviations were also not too restricted. The eclectic nature of teachers' beliefs about curriculum design implies that a science curriculum that has been designed on the basis of a single orientation is not likely to receive enthusiastic teacher support. The results of the one-way within-subjects ANOVA indicated that the differences among the five means were statistically significant (Wilks' lambda = .52, F (4, 806) = 184.39, $p < .001$). Paired-samples t tests revealed that only the difference between the means of the academic and society-centered orientations was not statistically significant.

The mean on the cognitive process subscale was the largest (Table 1). The reasons why Hong Kong science teachers were most enthusiastic about the cognitive processes orientation were not investigated in the present study. One tentative explanation is that the current science curricula in Hong Kong, designed in the early 1990s, were influenced by science education in the UK. According to Jenkins (1992), the essential characteristic of school science education in England and Wales in the 1980s is teaching the methods of science, that is, a process approach

Table 1
Descriptive Statistics and Reliability Estimates

Subscale / Item	Mean	Standard Deviation	Item-total Correlation
Academic (α = .76)	*5.86*	0.91	
Q 7	5.97	1.37	.58
Q 9	6.09	1.38	.48
Q14	6.18	1.33	.48
Q20	5.90	1.24	.58
Q24	5.10	1.41	.40
Q30	5.89	1.30	.52
Cognitive Process (α = .83)	*6.41*	0.98	
Q 1	6.56	1.35	.61
Q 4	6.81	1.15	.56
Q 6	6.17	1.25	.59
Q11	6.31	1.31	.71
Q33	6.19	1.31	.65
Society-centered (α = .77)	*5.87*	0.95	
Q 5	6.46	1.21	.46
Q13	5.32	1.57	.51
Q16	6.13	1.31	.60
Q19	5.68	1.40	.59
Q22	5.94	1.38	.41
Q32	5.72	1.41	.55
Humanistic (α = .79)	*5.59*	0.94	
Q12	4.87	1.73	.49
Q17	6.47	1.29	.42
Q21	5.48	1.43	.59
Q23	6.00	1.24	.53
Q26	4.89	1.47	.47
Q27	5.60	1.32	.63
Q29	5.82	1.29	.55
Technological (α =.74)	*5.97*	0.91	
Q 8	6.17	1.45	.47
Q15	6.16	1.33	.54
Q18	6.10	1.24	.52
Q25	5.63	1.36	.48
Q31	5.84	1.16	.52

Note. Means were based on a scale of 1 to 8. Means in italics are the mean SCOI subscale scores.

to school science education was prominent. Another plausible reason is that few Science-Technology-Society (STS) contents have been incorporated into the current science curricula in Hong Kong. The chemistry curriculum for secondary 6-7 students (Curriculum

Development Council, 1995), for example, devotes only 11% of the total teaching time to STS contents. Perhaps most science teachers in Hong Kong are not aware of the importance of the STS movement. Recently, the first author served as the instructor for a training course for chemistry teachers. It was a course designed for those who were going to be promoted to senior teachers.

There were a total of nine participating teachers who had had initial teacher training and taught secondary school chemistry for 6 to 24 years (mean = 16 years). When they were asked what "STS" stood for, only one of these teachers could provide the answer. A third possible explanation for the popularity of the cognitive processes orientation is that school-based assessment of science practical work as a component of the public examination system has been implemented for many years in Hong Kong. For example, school-based assessment of secondary 6-7 chemistry practical work was first implemented in 1978. Eighty percent of marks are allocated to assessment of chemistry students' process skills in laboratory work.

Hierarchical Confirmatory Factor Analysis of Teacher Data

The results of HCFA are depicted in Figure 2. All parameter estimates are presented in completely standardised form. The sample size was 706 because 104 out of the 810 science teachers in the sample had missing data. The standardised first-order and second-order factor loadings were all statistically significant. It is noteworthy that the hypothesised hierarchical model was very restrictive because there were 145 first-order factor loadings possible (i.e., 29 items x 5 factors) and five second-order factor loadings but 116 of the first-order factor loadings were fixed at zero. Overall model fit indices indicated that this restrictive model just fitted the data marginally (e.g., χ^2 (373) = 2355.24, goodness-of-fit index = .80, root mean square error of approximation = .091, comparative fit index = .77). Although the overall model fit was unsatisfactory, the target coefficient was equal to .923 (for the first-order model, χ^2(367)= 2173.13), indicating that the second-order factor explained 92.3% of the covariances among the five first-order factors. Because the target coefficient was very large and the overall model fit indices were unsatisfactory, misfit between the hypothesised hierarchical model and the real data was due to the specification of the first-order rather than the second-order factor structure. Hence, the existence of a second-order curriculum meta-orientation construct in science teachers' beliefs about curriculum design is evidenced.

Consistent with the hypothesised hierarchical model, the curriculum meta-orientation construct was substantially related to all the five specific curriculum orientations. The technological orientation factor obtained the highest second-order factor loading (γ = .99), meaning that a standard deviation change in the curriculum meta-orientation factor was associated with .99 standard deviation change in the technological orientation factor. The error variances in the society-centered, humanistic and technological factors were acceptable, but 65% of the variance of true score in the academic factor and 56% of the variance of true score in the cognitive processes factor could not be explained by the second-order factor.

The correlations among the five first-order factors are shown in Table 2. These correlations were based on latent constructs corrected for measurement error. All the ten correlations were considerable and positive. The correlation between the society-centered factor and the technological factor was the largest (r = .95), indicating that those science teachers who valued the society-centered orientation had a very strong tendency to support the technological orientation, and vice versa. Clearly, findings of the HCFA imply that complementary pluralism exists in science teachers' beliefs about curriculum design; the five alternative curriculum orientations described in Figure 1 are mutually complementary rather than mutually exclusive.

Table 2
Correlations Among the First-order Factors

Factors	1	2	3	4	5
1. Academic	1.00				
2. Cognitive Process	.60	1.00			
3. Society-centered	.77	.71	1.00		
4. Humanistic	.71	.65	.84	1.00	
5. Technological	.80	.74	.95	.87	1.00

In every science teacher's mind, the five alternative orientations to science curriculum are interconnected, resulting in a second-order curriculum meta-orientation. In other words, the belief system has a hierarchical structure as far as a science teacher's orientations to curriculum are concerned; the full set of alternative orientations to science curriculum forms the first-order structure while the curriculum meta-orientation represents the second-order structure.

Conceptually, the notion of curriculum meta-orientation is important because it may facilitate interpretation of some inconsistencies in science teachers' beliefs and classroom practices, which were observed by researchers. Aguirre, Haggerty and Linder (1990), for example, examined 74 Canadian preservice science teachers' conceptions of the nature of science, teaching, and learning by analysing their responses to 11 open-ended questions. One of their findings was:

> Almost 50% of the students saw learning just as an intake of knowledge. It was not always the same students that held the view that the function of science is to 'discover' the laws of nature, and the 'knowledge intake' view of learning (depicting a passive mind that obtains its 'content' through the senses, and which starts 'empty' when it comes to the classroom). But many of these students showed an implicit connection between the two views; that is, if they possessed the 'discovery' view of science they also possess the 'knowledge intake' view of learning. More research is necessary to verify that there is indeed a relationship between these two views and, if so, to identify the instructional implications. (Aguirre, Haggerty, & Linder, 1990, p. 389)

Similar apparently conflicting findings were reported by Berkheimer and Lott (1984). They surveyed 195 biology, chemistry and physics educators' perceptions of education objectives. Educators all viewed "concept development" the most important, but they also agreed to include "process," "application" and "science-based societal issues" as objectives. Along the same vein, Yager and Penick (1988) surveyed 940 the U.S. citizens' perceptions of the relative importance of four science goals: personal needs, societal issues, career education/awareness, and academic preparation. They found that citizens viewed academic preparation as the most important goal but they also valued the other three goals. Similar seemingly abnormal findings resulted from the investigations of Lantz and Kass (1987), McIntosh and Zeidler (1988), and Hewson, Kerby and Cook (1995).

Abnormal findings, such as those reported by the above researchers, might be explained using the concept of curriculum meta-orientation. Teacher beliefs about the nature of science, teaching and learning of science, science education goals, and science subject matter may be conceptualised as components of a belief system—the teacher beliefs about curriculum design. Perhaps researchers found varying degrees of inconsistency between different teacher beliefs or between teacher beliefs and classroom practice because they focused on a science teacher's individual beliefs but neglected the effect of clustering. Evidence from the present study has indicated that teacher beliefs are held in clusters, forming a hierarchical belief system. The clustering quality of teacher beliefs not only results in a curriculum meta-orientation but also integrates a set of conflicting curriculum orientations into a coherent system. Perhaps it is the curriculum meta-orientation that affects a science teacher's curricular decisions and classroom behaviour. Because the curriculum meta-orientation subsumes the academic, cognitive processes, society-centered, humanistic and technological curriculum orientations, it allows a science teacher to hold a set of conflicting education objectives simultaneously (e.g., concept development vs process), to adopt several incongruous models of science teaching in a single lesson (e.g., discovery method vs rote memory), or to select a group of inconsistent topics for a science curriculum (e.g., theoretical vs applied chemistry).

Different weightings of the five specific orientations yield different science curricula. It seems that a cluster of curriculum orientations, that is, a meta-orientation, has also been used to underpin some recent prominent science reforms in the USA, such as the *Project 2061* (AAAS, 1989), and the *National Science Education Standards* (National Research Council, 1996). However, finding effective mechanisms for facilitating teachers to operationise the meta-orientation in science classrooms is challenging. To promote scientific literacy, a meta-orientation must be embedded within not only an intended science curriculum, but also the implemented curriculum.

The Effects of Academic Disciplines and Teaching Experience

The two-way MANOVA indicated no statistically significant interaction between teachers' academic disciplines and teaching experience, Wilks' lambda = .914, $F\,(60, 3525) = 1.138$, $p = .219$, but statistically significant main effects for academic disciplines (Table 3) and teaching experience (Table 4). ANOVAs on each subscale were conducted as follow-up tests to the MANOVA. The familywise error rate for the five tests was set at .05/5 or .01 for each ANOVA using the Bonferroni method to control for Type I error across the five tests.

The ANOVAs on the society-centered scores and humanistic scores were statistically significant (Table 3). Post hoc analyses to the univariate ANOVA for the social-centered scores and humanistic scores were then conducted. Each pairwise comparison was tested at the alpha level of .01/6 or .0017 using the Bonferroni procedure to control for Type I error across the multiple comparisons. For the society-centered subscale, the mean for physics teachers was statistically different from that for integrated science, chemistry or biology teachers. The reasons why physics teachers are the least society-oriented were not investigated in the study. One plausible explanation is that the physics curricula in Hong Kong are dominated by the traditional contents; little attempt has been made to illustrate how physics is relevant to current societal issues. Post hoc analyses to the ANOVA for the humanistic scores also indicated that the mean for integrated science teachers was statistically different from that for physics teachers. Other pairwise comparisons were not statistically significant. The reasons why integrated science teachers were more humanistic than physics teachers are unknown. In Hong Kong, integrated science is offered for middle school (secondary 1-3) students only whereas only high school students are allowed to take chemistry, biology or physics. Perhaps integrated science teachers have less pressure from public examinations and thus they tend to use more student-centered learning activities to arouse student interest.

For the effect of teachers' teaching experience on the five SCOI subscale scores, all the five follow-up univariate ANOVAs were not statistically significant at the .01 level set by the Bonferroni method (Table 4). Because the MANOVA was statistically significant and the univariate ANOVAs were not statistically significant, the significant comparison may have

Table 3
Relationships between SCOI Subscale Means and Teachers' Academic Disciplines

Curriculum Orientation	Mean for each discipline group: Integrated science ($N = 105$)	Physics ($N = 203$)	Chemistry ($N = 181$)	Biology ($N = 288$)	F	p
Academic	5.80	5.81	5.93	5.89	.76	.52
Cognitive Process	6.42	6.30	6.52	6.44	1.66	.17
Society-centered	5.96	5.55	5.90	6.05	11.72	.00
Humanistic	5.89	5.44	5.54	5.60	5.61	.00
Technological	6.04	5.91	5.94	6.00	.65	.58

Note. Means were based on a scale of 1 to 8. Wilks lambda = .894, $F(15, 2123) = 5.869$, $p < .001$. Univariate F-tests with (3, 773) degrees of freedom.

involved some linear combination of the five subscale scores. As shown in Table 4, the *p*-values of the cognitive process and humanistic subscales were the lowest. Furthermore, teachers' cognitive process subscale means appeared to increase with teaching experience while their humanistic subscale means seemed to decrease with teaching experience. A discrepancy score was computed, which was equal to the absolute difference between a teacher's cognitive process subscale score and his/her humanistic subscale score. ANOVA was conducted to find out the effect of teaching experience on the discrepancy score. The results of the ANOVA indicated a statistically significant relationship between teaching experience and the mean discrepancy scores, $F\ (4, 788) = 6.04$, $p < .001$. Table 5 shows the means and standard deviations for the five experience groups. Levene's test indicated that the variances among the groups differed significantly, $F\ (4, 788) = 4.89$, $p = .001$. Dunnett's C method, a multiple comparison procedure that does not require equal population variances, was applied to assess further the differences among the five groups. It was found that teachers with more than eight years of teaching experience had statistically higher discrepancy scores than teachers with 0 to 2 or 3 to 4 years of experience. Also, teachers with 5 to 6 years of experience had statistically higher discrepancy scores than those with only 3 to 4 years of experience. This implies that the more experienced a teacher is, the more likely it is that the teacher values the cognitive processes orientation and ignores the humanistic orientation. Science educators in Hong Kong should find effective ways to facilitate teachers to use student-centered learning activities so that the gap between the cognitive processes and humanistic orientations can be narrowed.

Conclusion

In any country, improving the quality of science curricula is one of the perennial challenges facing educators and policy-makers. Given that the importance of teacher beliefs is undeniable, a deeper understanding of teachers' beliefs concerning the design of science curricula is critical. Numerous studies have examined science teachers' beliefs about the goals of science education, teaching strategies, and so on., but in the present study we have extended this line of research to the whole curriculum.

Table 4
Relationships Between the SCOI Subscale Means and Teachers' Teaching Experience

Curriculum Orientation	Years of teaching experience 0 – 2 (N = 71)	3 – 4 (N = 60)	5 – 6 (N = 96)	7 – 8 (N = 73)	> 8 (N = 493)	F	p
Academic	5.69	5.84	5.77	5.91	5.90	1.17	.32
Cognitive Process	6.32	6.31	6.18	6.52	6.47	2.28	.06
Society-centered	5.84	6.05	5.79	6.03	5.85	1.29	.27
Humanistic	5.69	5.83	5.52	5.81	5.52	3.01	.02
Technological	5.96	6.05	5.83	6.10	5.97	1.03	.39

Note. Means were based on a scale of 1 to 8. Wilks lambda = .953, $F(20, 2601) = 1.918$, p = .008. Univariate F-tests with (4, 788) degrees of freedom.

Five orientations to science curriculum were conceptualised in the study. Consistent with the findings of Cheung and Ng (submitted), we found that the five curriculum orientations clustered together to form a superordinate curriculum meta-orientation (Cheung, 2000), thus making it possible for a science teacher to hold several apparently rival orientations. The relations among the five specific orientations were precisely determined; they were all positively correlated to form the first-order structure of the hierarchical belief system. The present study also revealed that Hong Kong teachers' beliefs about curriculum design were related to science disciplines. We found no statistically significant change in science teachers' beliefs about any of the five specific curriculum orientations when they had gained more teaching experience. However, the more experienced a science teacher was, the wider was the gap between his/her beliefs about the cognitive processes and humanistic orientations.

Hence, the present research has reinforced the findings of Cheung and Ng (submitted) in their work on teachers' beliefs about curriculum design. More importantly, our study has provided the groundwork for exploring teachers' beliefs about the design of science curricula. As the first-order structure of our hypothesised hierarchical model (Figure 2) requires improvement in order to provide better model fit, we are currently refining the classification scheme for curriculum orientations in science education and the SCOI. It is likely that the relations among the five specific curriculum orientations are context-dependent, and efforts are also made to replicate the present investigation in other countries and cultures.

Table 5
Mean Discrepancy Scores for the Five Teaching Experience Groups

Teaching Experience	No. of Teachers	Mean	SD	Statistical significance 0 – 2 yrs	3 – 4 yrs	5 – 6 yrs	7 – 8 yrs
0 – 2 years	71	0.81	0.62				
3 – 4 years	60	0.67	0.46	ns			
5 – 6 years	96	0.95	0.70	ns	*		
7 – 8 years	73	0.90	0.70	ns	ns	ns	
> 8 years	493	1.09	0.80	*	*	ns	ns

Note. ns = statistically nonsignificant differences between pairs of means, while an asterisk (*) = significant differences at the .05 level using the Dunnett's C procedure.

Acknowledgements

The authors would like to thank Se-Yuen Mak and Din-Yan Yip for their kind assistance during the study and Kit-Tai Hau for his comments on an earlier draft of this paper.

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Appendix 1
Examples of the SCOI Items

Orientation 1: Academic Curriculum

- I believe that science curriculum should be based on knowledge of the natural sciences.
- Scientific concepts are the best organising centre of curriculum for secondary school science.
- Science curriculum must provide students with knowledge so that they are prepared for more advanced study in sciences and become professional scientists or engineers.

Orientation 2: Cognitive Processes Curriculum

- I believe that the most valuable science curriculum contents are inquiry skills such as observing, measuring, hypothesising, experimenting, and controlling variables.
- The basic goal of science curriculum should be the development of students' cognitive skills, such as inferring and problem solving, which can be applied to learning virtually anything.
- I believe that secondary school science curriculum should be based on the methodologies of inquiry in sciences.

Orientation 3: Society-centred Curriculum

- Science curriculum contents should focus on societal problems such as genetic engineering and energy shortage.
- I believe that science is a tool to improve our society.
- Secondary school science curriculum should use societal issues as the organising centre of curriculum content, such as pollution and population explosion.

Orientation 4: Humanistic Curriculum

- I believe that students are the crucial basis of science education, its aim is to promote student personal growth and to meet student needs for coping with living in a technological world.
- Students should learn history of science (e.g., the trial of Galileo) and thus understand how humankind has influenced the development of science.
- Science curriculum should be concerned with how a student's affective, cognitive, and psychomotor development can be integrated.

Orientation 5: Technological Curriculum

- The design of science curricula should focus on finding efficient teaching methods to achieve a set of predetermined learning objectives.
- Science students should understand the importance of technologies, such as their contributions to transport, health, and communication.
- Students should understand the applications of science in technology and industry.