How Close Student Teachers' Educational Philosophies and Their Scientific Thinking Processes in Science Education

Kemal Yurumezoglu*, Ayse Oguz**

** Secondary Science and Mathematic Education Department*
The Mugla University College of Education
48000 Kotekli-Mugla TURKEY
k.yurumezoglu@mu.edu.tr
*** Elementary Education Department*
The Mugla University College of Education
48000 Kotekli-Mugla TURKEY
ayseoguz@mu.edu.tr

ABSTRACT. For being guidance, science teachers should be framed by strong content knowledge to construct scientific thinking process as a scaffold. The aim of this research was to look at student teachers' scientific thinking processes. Then, the results compared with their educational philosophy. During the study, two different instruments were used. For measuring each student's scientific thinking processes, the authors developed two scenarios. In addition, educational philosophy self-assessment test was conducted to the thirty-two junior student teachers. In this study, the combinations of qualitative and quantitative methods were used. All data were in the form of paper and pencil. Iterative process of open coding was used to analyze the scenarios. The educational philosophy self-assessment test was ported into a Microsoft Office Excel program 2003 to calculate frequency and percentage. The results showed that there was a big gap between what students thought and what they did. Even though they supported constructivism in education, they tended to make interpretations in terms of their common sense. The authors stated that the gap between scientific thinking and common sense and habitude interpretations could only be closed by using scientific thinking processes as a scaffold.

KEY-WORS : educational philosophy, scientific thinking, psychological orientations, scaffolding

1. Introduction

What the future holds in store for individual human beings, the nation, and the world depends largely on the wisdom with which human use science and technology. And that, in turn, depends on the character, distribution, and effectiveness of the education that people receive.

Many science education programs (AAAS, 1989; Republic of Turkey Ministry of National Education, 2002) support the idea that active, hands-on (la main a la pate), and student-centered inquiry should be at the core of a good science education. A major goal is to improve science education and ultimately achieve higher levels of scientific literacy for all students. The programs intend to provide support for integrity of science in science programs by presenting and discussing criteria for improvement of science education.

More than ever before, educators agree that science education should be based on asking questions, conducting investigations, collecting data, and looking for answers (e.g. Schneider, Krajcik, Marx, & Soloway, 2002; Singer, Marx, & Krajcik, 2000). In addition, instead of memorizing the scientific facts, learners should be encouraged to use the scientific thinking process. The best way to learn science is to *do science*. Strategies for *do science* should focus on selecting projects of interest to the learners and having them apply concepts and skills from other content areas.

The deep connection between levels of content knowledge and the scientific thinking process has important implications for science education. The studies on content knowledge factor indicated that school science instruction needs to pay attention to the interaction of evolving content knowledge and evolving scientific thinking process. Although the research base linking the quality of content knowledge and the quality of process appears stronger in science cognition, this connection is generally poorly reflected in science instruction.

There are now a number of classroom-based experiments that aim to apply these ideas to children's science instruction. For example, Rosebery, Warren and Conant (1992) have developed an approach to science instruction that emphasis collaboration. The researchers` goal was that children actually *do science* and they engaged in the full scope of scientific thinking process with a remarkable degree of regulation on the part of children themselves. They generated their own questions, planned their research, collected and interpreted data, and developed and refined their theories. The researchers reported growth in both scientific thinking process and science content knowledge.

As one can understand from the above recommendations science teaching is a complex activity. Therefore, teachers of science at all grade levels should always monitor and evaluate their students as a guide. This can be expressed by sociocultural theory. Sensitive instruction at the novice's cutting edge of understanding, in Vygotsky`s (1978) "zone of proximal development" (p.84) encourages participation at a comfortable yet challenging level and provides a bridge for generalizing skills and approaches from familiar to novel situations. Teaching in the ZPD provides a "scaffold" to support the child in learning. As learners become more component, the teacher gradually withdraws the scaffolding so learners can perform independently. The key is to ensure that the scaffolding keeps learners in the ZPD.

Scientific thinking processes can be think as a scaffold in science classes because that involves several procedural and conceptual activities such as asking questions, hypothesizing, designing, experiments, using apparatus, observing, measuring, predicting, recording and interpreting data, testing, evaluating evidence, performing statistical calculations, making inferences, and formulating theories and models. This focus ensures the development of unifying the knowledge (e.g., Spelke, 1991; Vosniadou & Ionnides 1998). However, sometimes students fail to make connections and reach the conclusions. Is this the reason of children's lack of scientific reasoning ability or teachers' lack of being guidance to teach scientific thinking processes?

Metz (1998) claimed that "developmentally appropriate" science curricula significantly underestimate the potential of children's scientific reasoning ability. Moreover, not only Goswani (1998) but also Klahr (2000) described that both fundamental and higher-order cognitive processes are well established by the end of the first year of life. These cognitive processes are perception, attention, learning, memory, knowledge representation, reasoning and problem solving. In addition, Glaser (1981) found that while experts categorized physics problem in terms of abstract principles, adults with little knowledge categorized physics problem at the level of surface features. What is more, Chi (1978) compared the performance of child domain-specific experts with adults' novices with the abilities of the child chess experts and adult chess novices.

Thus, the deficiencies of scientific reasoning in children should be questioned whether it is due to their developmental shortcomings or due to their poor science content knowledge or due to their teachers poor guidance in science classes. For being guidance, science teachers should be framed by strong content knowledge for constructing the scientific thinking process as a scaffold. Therefore, the aim of this research was to look at pre-service teachers' scientific thinking processes. Then, the results compared with their educational philosophy. The main goal is to look at how close junior student teachers' philosophy and their scientific thinking processes.

2. Method

2.1. Instructional context

The study was conducted at a public university located in the Mediterranean region of Turkey with junior student teachers enrolled in the department of Science Education in Primary School Teaching. Students of this department had already completed within the years the basic physics, chemistry, biology and educational courses before the study were conducted. This investigation focused on determining whether student teacher' scientific thinking processes are reflected their educational philosophy»

2.2. Participants

The participants were junior student teachers enrolled at the four year public college. The student populations of the school were selected to the college according to their scores on the nationwide centralized university entrance exam and their preferences. Generally coming from middle class working families, students come to the college from the different parts of the nation. Data were collected in spring semester of 2007 and included thirty two junior student teachers (twenty boys, twelve girls) from the department of Science Education in Primary School Teaching.

2.3. Instruments

During the study, two different instruments were used to compare students' scientific thinking processes and their educational philosophies. For measuring each student's scientific thinking processes two scenarios were developed by the authors (see appendix 1). In the first scenario, a case about environmental pollution was given. In this case, the effects of acid rain were discussed from several perspectives. The question was making inferences based on given perspectives. In the second scenario, an experimental design example was given. The question for the student was to design an experiment to test the soil acidity. The main goal for scenario two was to look at student teachers' scientific thinking ability in given problem. In another words, the aim was to observe student teachers' approaches to the problem. It is whether scientific or non-scientific.

Philosophy often seems rather remote and disconnected from everyday life, but it is not at all the case. Everyone has a philosophy of life and it is what guides one's in his daily actions. This thought can be transferred to educational philosophy of teachers that might important to reflect their actions in the classrooms. Therefore, educational philosophy self-assessment test (Cohen, 1999) was conducted to the student teachers.

The assessment contain forty items with five linkert-scale degreed from strongly agree to strongly disagree. The assessment developed to measure four educational philosophies: (1) perennialism, (2) essentialism, (3) progressivism, and (4) reconstructionalism/critical theory and four psychological orientations (related theories of learning): (1) information processing, (2) behaviorism, (3) cognitivism/constructivism, and (4) humanism (see appendix 2). All these educational philosophies and psychological orientations have their roots from world philosophies. These philosophies and theories were summarized in Appendix 1.

3. Data analysis and coding procedure

In this study, the combination of qualitative and quantitative methods that named mixed design was used. All data were in the form of paper and pencil. Iterative process of open coding was used to analyze the scenarios (Strauss & Corbin, 1998). The educational philosophy self-assessment test was ported into a Microsoft Office Excel program 2003. Frequency and percentage measures were done based on the scoring table in appendix 3. The coding schemes of the qualitative data were contracted by two researchers. Both are doctorate in college of education. To establish the reliability, each data were analyzed depending on the coding scheme by the researchers.

In the first scenario, three situations were given to the participants to interpret the scenario. First, the researchers analyzed students' interpretations based on three criteria: (1) interpretation by habitude, (2) interpretation by common sense, and (3) interpretation by scientifically. Then the researchers categorized the interpretations in terms of the dominant reasoning types such as causal, sequential, experimental, inductive, deductive, dialectic, conditional, …. and uncertain. The coding scheme for scenario 1 and an example of coding from students' data are presented in Table 2.

As presented in the table 2 student 30 started the interpretation for situation 2 by saying "*…according to me it's plausible…*" and continued "*…I did not found this idea logical…*" The participant did not mention any scientific explanations such as why he is thinking like that. But later on, the participant made scientific interpretations by the end of his task. Interpretation by habitude was obvious in student 5 data, because there were no knowledge and processes presented in the essay.

In the second scenario, participants' scientific reasoning processes were tested by asking designing an experiment. The researchers analyzed students' writing in terms of the experimental processes that widely accepted by the scientific community: (1) observation, (2) research question, (3) hypothesis, (4) experimentation, (5) results, (6) interpretation, (7) conclusion, and (8) sequentially. The coding scheme for scenario 2 and an example of coding from student's data are presented in Table 3.

Table 2: Coding protocol and an example for scenario 1.

Coding Protocol for scenario 1			
Examples from student data	interpretation by habitude	interpretation by common sense	interpretation by scientifically
Student 30 interpretatio n		*…according to me it's plausible that pesticides are not useful for farms…I did not found this idea logical…* (Experimental reasoning)	*…I am suspicious of all given situations, because the only changes might not be the rocks. The similar context should be developed in lab. Environment and should be tested…then I could only be persuaded…* (Experimental reasoning and inductive reasoning)
Student 5 interpretatio n	*…whether the water takes away the effects of chemicals that lost its effects…*(uncertain)		

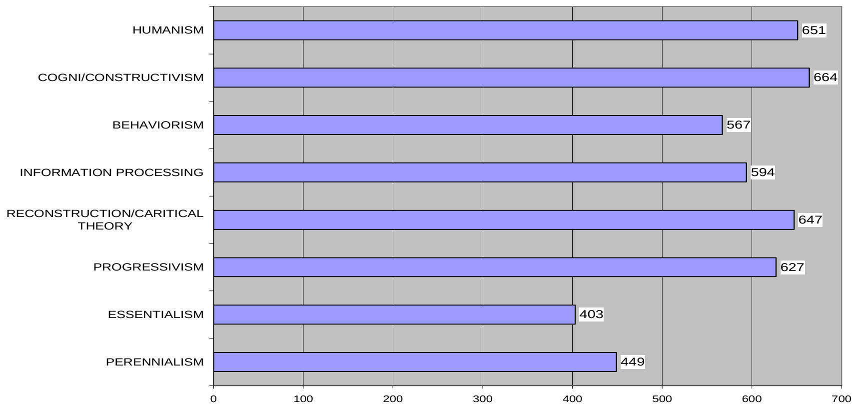
Table 3: Coding protocol and an example for scenario 2.

Coding Protocol for scenario 1	An example from student 20 experimental processes
Observation (pre-research)	*…the soil and other possible absorbsion matters are used to analyze the soil and the acid…*
Research question	*…To understand the soil acidity and whether it is absorb the water…*
Hypothesis	*…If a neutralization reaction occurs in the soil, there might be base matters in it and after neutralization some salt and some water should be retained in the soil…*
Experimentation	*…During the experiment, physical and chemical analyze methods will be used…*
Interpretation	*…If basic solution's pH decreases that means neutralization is started…*
Conclusion	*…Even though the soil neutralized the acid that can not generalized for every soil…*
sequentially	The data is sequential in terms of scientific processes.

4. Results

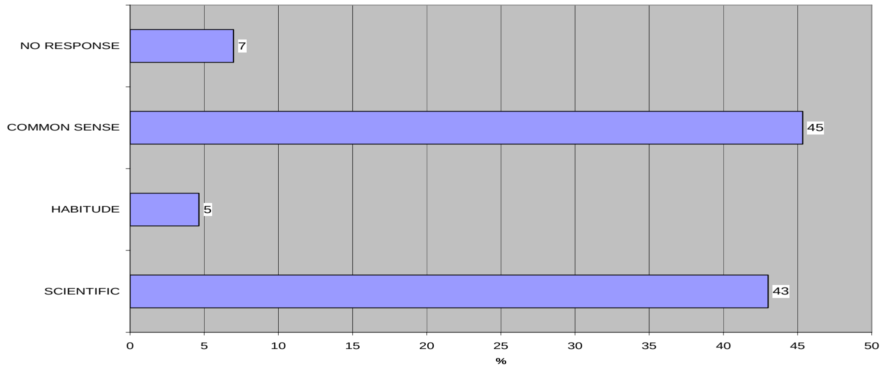
During the study, two different instruments were conducted. One was students' educational philosophy and the other was students' scientific thinking processes. In Figure 1 students' educational philosophy was represented. According to he figure, students responses heaped up around two psychological orientates that are cognitivism/constructivism and humanism respectively. Reconstruction/critical theory and progressivism were students' highest preference as educational philosophies. Essentialism and perennialism were students least choices respectively.

Figure 1: Students' educational philosophies



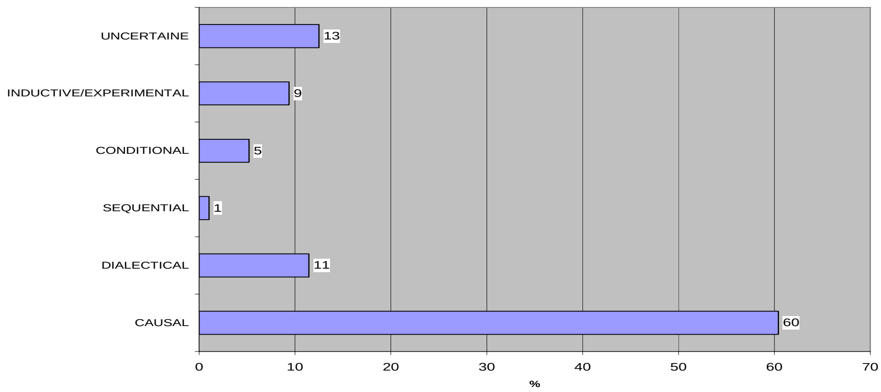
Student teachers' interpretations for scenario 1 analyzed based on three criteria (habituate, common sense, and scientific) and the results summarized in Figure 2. Although majority of student believed in science, only % 43 of student teachers' interpretation were scientifically. According to the figure, % 45 of students tended to interpret in terms of their common sense.

Figure 2: Student interpretations for scenario 1



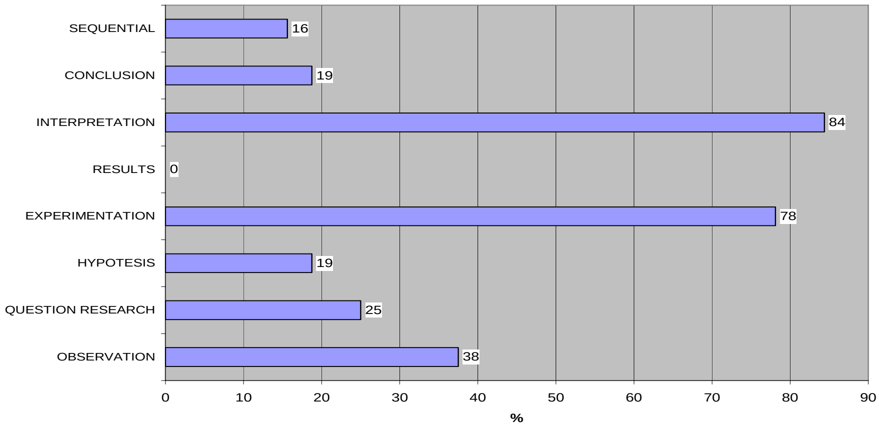
Students' interpretations based on the dominant reasoning types (such as causal, sequential, experimental, inductive, deductive, dialectic, conditional,…. and uncertain) were showed in figure 3. More than half of the students' responses (%60) were had a tendency to causal reasoning.

Figure 3: Students' reasoning type scenario 1



In figure 4, student teachers' scientific reasoning processes that were tested by designing an experiment represented. Majority of students (%84) were tended to made some interpretations whereas only %19 of students were tended to made hypothesis. Therefore, barely % 16 of participants' scientific thinking processes showed sequentially. In the second scenario, the researchers only expected from students to design an experiment not apply it in the laboratory. This is why student did not presented any results in their essays. However, even though students gathered around constructivism only a quarter of students construct a research question in an experimental design process.

Figure 4: Scientific thinking processes of students' experimental design for scenario 2



5. Conclusion

Students and teachers face many more pressures today than they did in 1940s, and yet it appears that most of the classes are still teacher- directed and dominated. Students are still looking for right or wrong answers and not learning how to think. It looks like we could not do much good about Deweyan wisdom that education must pay more attention to the development of the students` minds.

In this research student teachers' educational philosophy and their scientific thinking processes were studied to understand how close they each other. The results showed that there was a big gap between what students thought and what they did. Even though they supported constructivism in education, they were tended to make interpretations in terms of their common sense.

Majority of participants presented more than one interpretations in their essays. Especially common sense and scientific interpretations were interrelated each other. On the other hand, the essays with poor scientific explanation were framed around habitude interpretations. Therefore, it might be concluded that students with common sense are closer to scientific thinking than students with habitude thoughts. The authors stated that the gap between scientific thinking and common sense and habitude interpretations could only be closed by using scientific thinking processes as a scaffold.

Information is increasing and social changes are also racing far ahead of educational changes. There is no way that teachers can transmit either volumes of information or that kind of social changes. What teachers can teach is how to find the information and interpret, analyze and use it constructively in social context. Classes framed around scientific thinking processes could enable this kind of information because the thinking process is a broad idea that one could evaluate information from several perspectives.

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Appendix 1

Philosophy and education continuum chart
(Available online at http://oregonstate.edu/instruct/ed416/chart3.html).

Modernity <---> Post Modernity **Traditional and Conservative <---------------------------------> Contemporary and Liberal** **Authoritarian (convergent) <--------------------------------> (divergent) Non-Authoritarian**				
General or World Philosophies	**Idealism:** Ideas are the only true reality, the only thing worth knowing. Focus: *Mind*	**Realism:** Reality exists independent of human mind. World of physical objects ultimate reality. Focus: *Body*	**Pragmatism:** Universe is dynamic, evolving. Purpose of thought is action. Truth is relative. Focus: *Experience*	**Existentialism:** Reality is subjective, within the individual. Individual rather than external standards. Focus: *Freedom*
Originator(s)	Plato, Socrates	Aristotle	Pierce, Dewey	Sartre, Kierkegaard
Curricular Emphasis	Subject matter of mind: literature, history, philosophy, religion	Subject matter of physical world: science, math	Subject matter of social experience. Creation of new social order	Subject matter of personal choice
Teaching Method	Teach for handling ideas: lecture, discussion	Teach for mastery of facts and basic skills: demonstration, recitation	Problem solving: Project method	Individual as entity within social context
Character Development	Imitating examples, heroes	Training in rules of conduct	Making group decisions in light of consequences	Individual responsibility for decisions and preferences
Related Educational Philosophies	**Perennialism:** Focus: Teach ideas that are everlasting. Seek enduring truths which are constant, not changing, through great literature, art, philosophy, religion.	**Essentialism:** Focus: Teach the common core, "the basics" of information and skills (cultural heritage) needed for citizenship. (Curriculum can change slowly)	**Progressivism:** Focus: Ideas should be tested by active experimentation. Learning rooted in questions of learners in interaction with others. Experience and student centered.	**Reconstructionism/ Critical Theory** Focus: Critical pedagogy: Analysis of world events, controversial issues and diversity to provide vision for better world and social change.

Key Proponents	Robert Hutchins, Jacque Maritain, Mortimer Adler, Allan Bloom	William Bagley; Arthur Bestor, E. D. Hirsch, Chester Finn, Diane Ravitch, Theodore Sizer	John Dewey, William Kilpatrick	George Counts, J. Habermas, Ivan Illich, Henry Giroux, Paulo Freire
Related Theories of Learning (Psychological Orientations)	**Information Processing** The mind makes meaning through symbol-processing structures of a fixed body of knowledge. Describes how information is received, processed, stored, and retrieved from the mind.	**Behaviorism** Behavior shaped by design and determined by forces in environment. Learning occurs as result of reinforcing responses to stimuli. **Social Learning** Learning by observing and imitating others.	**Cognitivism/ Constructivism** Learner actively constructs own understandings of reality through interaction with environment and reflection on actions. Student-centered learning around conflicts to present knowing structures.	**Humanism** Personal freedom, choice, responsibility. Achievement motivation towards highest levels. Control of own destiny. Child centered. Interaction with others.
Key proponents	R. M. Gagne, E. Gagne, Robert Sternberg, J.R. Anderson	Ivan Pavlov, John Watson, B.F. Skinner, E.L. Thorndike, Albert Bandura	Jean Piaget, U. Bronfenbrenner, Jerome Bruner, Lev Vygotsky	J.J. Rousseau, A. Maslow, C. Rogers, A. Combs, R. May

Appendix 2

Scenario 1

Trees in North America and Europe are dying at an alarming rate. Among the many possible causes is acid rain. Studies suggest that acid rain destroys essential nutrients in the soil and damages the trees` delicate roots. As trees weaken from lack of food, they are unable to survive insect attacks, drought, and heavy frosts. In time, they die from these causes. However, some forests have managed to stay healthy.

Your job is to find out how some forests manage to stay healthy. Here some interpretations from the farmers who are living in that zone. Please read all of the interpretations and decide which one or ones are appropriate and inappropriate.

1. Farmer: Now-a-days we regularly use pesticides to control insects. When pesticides are applied to land, residues may run off into streams and lake, these chemicals reduce the causes of acid rain.

2. Farmer: Some forests have managed to stay healthy, because natural substances in surrounding rocks protect them. These substances are called “*buffer*”. One of the commonly known buffers is limestone. Like other buffers, limestone can neutralize acids. So acid rain causes little or no damage in the areas with limestone.

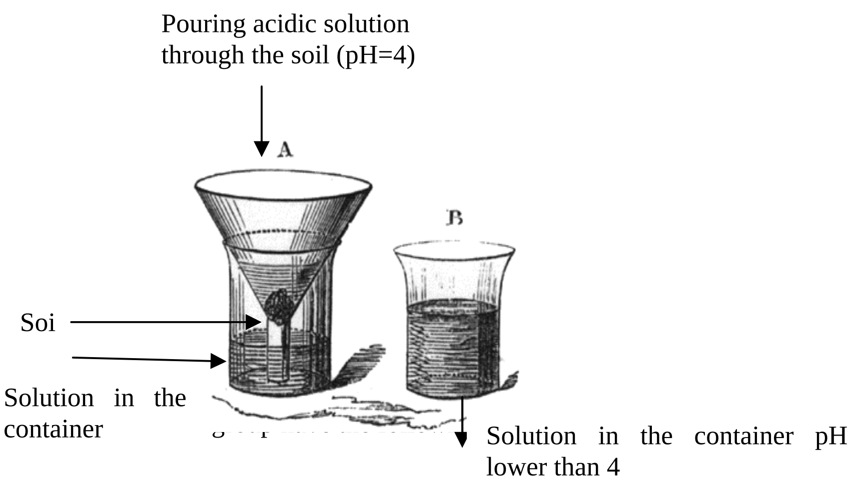
3. Farmer: In some regions the weather is hot, so the rain on the ground evaporates quickly. As a result the damage of the acid rain disappears.

Do you agree with any of these farmers? Describe in detail why do you agree with him?

If you do not agree with any one of them, then also describe why you do not agree with them.

Scenario 2

Senay made an acidic solution by adding vinegar to 1 cup (250ml) of tap water until the pH (acidic level) was 4.0 and poured the solution over the soil so that it dripped through the filter into the container. Then she used litmus paper to tests the pH of the solution in the container. The pH was lower than 4.0.



Students in Senay’s group have the following explanations. With whom would you agree? Give you reasons in detail.

Emir: Soil absorbs some water and acid, so there is less acid in the water that comes out.

Cigdem: This soil neutralizes the acid.

Deniz: All soil neutralizes acid so there is less acid in the water that comes out.

They could not agree on an answer. What kind of experiment they could design to find out who is right?

Appendix 3

Educational Philosophies Self-Assessment Scoring Guide

Record the number you chose for each statement in the self-assessment in the spaces given. Add the numbers for each section to obtain your score for that section. The highest score(s) indicates your educational philosophy and psychological orientation.

Perennialism

The acquisition of knowledge about the great ideas of western culture, including understanding reality, truth, value, and beauty, is the aim of education. Thus, curricula should remain constant across time and context. Cultivation of the intellect is the highest priority of an education. Teachers should directly instruct the great works of literature and art and other core curricula (The total scores of questions 1, 10, 23, 31, and 39 are related to this philosophy).

Essentialism

Essentialists believe that there is a core of basic knowledge and skills that needs to be transmitted to students in a systematic, disciplined way. A practical focus, rather than social policy, and emphasis on intellectual and moral standards should be transmitted by the schools. It is a back-to-basics movement that emphasizes facts. Instruction is uniform, direct, and subject-centered. Students should be taught discipline, hard work, and respect for authority (The total scores of questions 5, 7, 12, 16, and 17 are related to this philosophy).

Progressivism

Progressivists believe that education should focus on the child rather than the subject matter. The students' interests are important, as is integration of thinking, feeling, and doing. Learners should be active and learn to solve problems by experimenting and reflecting on their experience. Schools should help students develop personal and social values so that they can become thoughtful, productive citizens. Because society is always changing, new ideas are important to make the future better than the past (The total scores of questions 4, 24, 26, 34, and 36 are related to this philosophy).

Reconstructionism/Critical Theory

Social reconstructionists advocate that schools should take the lead to reconstruct society in order to create a better world. Schools have more than a responsibility to transmit knowledge, they have the mission to transform society as well. Reconstructionists use critical thinking skills, inquiry, question-asking, and the taking of action as teaching strategies. Students learn to handle controversy and to recognize multiple perspectives (The total scores of questions 8, 11, 15, 25, and 40 are related to this philosophy).

Information Processing

For information processing theorists, the focus is on how the mind of the individual works. The mind is considered to be analogous a computer. It uses symbols to encode, process, remember, and retrieve information. It explains how a given body of information is learned and suggests strategies to improve processing and memory (The total scores of questions 6, 14, 22, 29, and 37 are related to this philosophy).

Behaviorism

Behaviorists believe that behavior is the result of external forces that cause humans to behave in predictable ways, rather than from free will. Observable behavior rather than internal thought processes is the focus; learning is manifested by a change in behavior. This is known as the stimulus-response theory of learning. The teacher reinforces what what the student to do again and again and ignores undesirable behaviors. The teacher's role is to develop behavioral goals and establish reinforcers to accomplish goals (The total scores of questions 20, 30, 33, 35, and 38 are related to this philosophy).

Cognitivism/Constructivism

The learner actively constructs his or her own understandings of reality through acting upon and reflecting on experiences in the world. When a new object, event, or experience does not fit the learner's present knowing structures, a conflict is provoked that requires an active quest to restore a balance. Teachers facilitate environmental conditions and mediate experiences to support student learning (The total scores of questions 2, 9, 19, 27 and 32 are related to this philosophy).

Humanism

Humanist educators consider learning from the perspective of the human potential for growth, becoming the best one can be. The shift is to the study of affective as well as cognitive dimensions of learning. Beliefs include: human beings can control their own destiny; people are inherently good and will strive for a better world; people are free to act but must be responsible; behavior is the consequence of human choice; and people possess unlimited potential for growth and development. There is a natural tendency for people to learn, which will flourish if nourishing, encouraging environments are provided (The total scores of questions 3, 13, 18, 21 and 28 are related to this philosophy).