Global Social Sciences Review (GSSR)
Vol. IV, **No.** III (Summer 2019) | **Page:** 221– 228

Teachers' Misconceptions in Science: Implications for Developing a Remedial Teacher Training Program

Saria Rasul — Department of Education, University of Management Technology Lahore, Punjab, Pakistan.
Email: rasul.saria@yahoo.com

Abid Shahzad — Assistant Professor, Department of Education, The Islamia University of Bahawalpur, Punjab, Pakistan.

Zafar Iqbal — Adjunct Professor, Director Graduate Studies UMT Lahore, Punjab, Pakistan.

Abstract *This study is designed to investigate future teachers' misconceptions in heat and temperature concepts. The objectives of the study were to find out (i) misconceptions of future teachers in concepts of heat and temperature, (ii) to develop a counteractive teacher-training program for certain misconceptions and (iii) to establish the efficiency of treatment. The study sample was 96 prospective science teachers. Convenient sampling method was used in the study. Data from 96 respondents were collected in phase one of the study. Experimental treatment (lesson) based on the 5Es learning model was prepared in the second phase of the study and implemented in the third phase of research. A two tiers test, consisting of 12 items was used to collect data. Each tier was based on choices. The data were analyzed using ANOVA and t-test. The study explored the misconceptions of prospective teachers' about heat and temperature concepts and established the importance of experimental treatment.*

Key Words
Science Education, Prospective Science Teacher, Misconceptions, Constructivism, Conceptual Change, Heat and Temperature Concepts

Introduction

Science education is becoming important with every passing day due to its increasing role in the life of individuals. Due to the importance of science education learning of science concepts is critical for the learner. (Bodner 1986; Jonassen 1991; Sanger & Greenbowe 1997). To enhance learning there is a need that learner has no misconceptions in their prior knowledge (Andersson 1986). According to Ausubel (1968), teachers must discover students' prior knowledge about concepts and then teaching should be designed. Teachers should be trained to diagnose and overcome misconceptions of students. However, most teachers are concerned with only teaching and not giving importance to the identification of misconceptions and overcoming them. Role of teacher is very important for overcoming learners' misconceptions. Literature proves that to improve teaching there is a need to identify misconceptions of teachers (Lawrenz, 1986; Beck et al., 2000; Kikas, 2004).

Traditional instructions are usually ineffective to overcome misconceptions of learners. There is a need for paradigm shift in teaching methods from teacher centered teaching to learner-centered teaching (Laws et al., 1999; Reddish et al.1997). Quality teaching in science is crucial for enhancing students' learning, developing conceptual understanding, and increasing scientific literacy and to increase the economic productivity of the country. The National Commission on Teaching and America's Future (NCTAF, 1997 states (as cited by Ogunmade, 2005 p22) that excellent teaching requires teachers that are competent in subject matter knowledge, pedagogical content knowledge and know learners previous knowledge; can build supportive and thought-provoking class environment; can create good interaction within students and colleagues. Research (Shulman 1986) noted that pedagogical content knowledge of teacher must include knowledge of students' misconceptions in concepts. Reducing the misconceptions of teachers is very important for improving the quality of education.

p-ISSN 2520-0348 | **e-ISSN** 2616-793X | **L-ISSN** 2616-793X | **DOI:** 10.31703/gssr.2019(IV-III).28 | **URL:** http://dx.doi.org/10.31703/gssr.2019(IV-III).28

According to Hodson (2008), teaching which is designed to overcome misconceptions has following steps

1. Explore learner' conceptions.
2. Arrange opportunities to diagnose students' concepts.
3. Motivate the students to bring changes in their concepts where needed and alter them if they are wrong.
4. Help in restructuring concepts of students.

Research literature revealed that like many other concepts misconceptions are very common in heat and temperature concepts. (Paik, Cho, & Go 2007; Sozbilir, 2003; Yeo & Zadnik 2001; Carlton, 2000; Niaz 2000; Harrison, Grayson, & Treagust 1999; Kesidou & Duit 1993;Erickson 1979)This study was designed to explore the misconceptions of prospective teachers in these concepts during training so that a better training program can be designed keeping in view of misconceptions of students. Literature (Lawrenz, 1986; Beck et al., 2000; Kikas, 2004;) established the importance of such researches to improve teacher training for overcoming misconceptions of teachers in concepts.

Statement of the Problem

Science teachers are responsible for their students' concepts during learning of science (Dantonio & Beisenherz, 2001). Learning of science will not be effective without overcoming misconceptions of students. This research study was an investigation to identify prospective science teachers' misconceptions about heat and temperature concepts.

Objectives of the study

Following were the Objectives of the Current Study.

1. To discover the misconstructions of future science teachers regarding heat and temperature.
2. To cultivate a helpful teachers' training program in the selected concept areas.
3. To establish the efficiency of the counteractive training program to overcome diagnosed misconceptions in selected concept areas.

Procedure of Study

The current study was set up in three phases; in the first phase, (i) twelve two tiers items were used to explore misconceptions regarding temperature and heat concepts (ii) lessons based on the 5'Es model were developed. In the last phase of the study treatment based on these lessons was given and posttest was taken to check the effectiveness of treatment.

Methodology

Design of the study

A quasi-experimental design (pre-test, post-test) was applied to this study. Pretest-posttest nonequivalent control group research design was used in this study. According to Cresswell (2003), pretest-posttest de-signs are helpful for comparing groups and to check the effectiveness of treatment.

Population

All prospective science teachers of B.Ed. programs in GOVT teacher training institutes of Punjab were taken as population.

Sample

Sample in phase one of the study consisted of 96 prospective science teachers selected from 10 teacher training colleges and 5 regional campuses of Allama Iqbal Open University by convenient sampling method representing B.Ed. (regular), B.Ed. (HONS) and B.Ed. (distance). Sample for phase three was selected on the basis of lab facilities in institutes. The researcher requested to heads of these selected institutes for permission to conduct the study. Finally, the researcher got permission in two of these institutes. These institutes were nominated randomly as an experimental and control group.

Instrument

An instrument containing 12 two-tier MCQs items, was used for the data collection purpose. The first one is based on multiple-choice questions, while the other tier is also based on possible reasons for all probable reactions of the first tier. The extensive related literature review was done to extract possible questions (Weiss, 2010; Tanahoung,

Chitaree, & Soankwan, 2010; Yeo & Zadnik, 2001; Wiser, 1986). This study established numerous misconceptions that are in-line with past studies.

Reliability and Validity of Instrument

The validity of the test was established by experts' opinion and pilot testing. Reliability of test was statistically calculated by Cronbach alpha and was found 0.65.

Review of Literature

Importance of Science Education

Knowledge of science is important for solving problems of life. It is important for social and economic progress of the country. Due to such reasons, scientific literacy is given importance in every country. According to literature (AAAS, 1993; Bell et al, 2003; Bianchini & Solomon, 2003; Bybee, 1997; National Research Council, 1996), science education helps individuals and nations in many aspects of life such as:

2. Improvement in economic output of the country.
3. Resolve the problems of human by developing a skill for such purposes.
4. Improvement in the lives of individuals.
5. Able the individuals to discuss scientific and technological issues.

Role of Teacher and Teaching Method in Overcoming Misconceptions of Concepts

The teacher has key importance in the system of education. They play an important role in the development of the country by giving knowledge to students. That is why the teacher should be well trained to bring an understanding of concepts. According to Gujjar (2013). According to Polland and Tann (1993), the quality teacher must have sufficient knowledge, for the teaching of the subject, student assessment and classroom management and opportunities for regular professional learning. Quality teachers must have; professional development opportunities; sufficient subject matter knowledge; inquiry-oriented teaching approaches, emphasize on development of skills in learner such as observation, questioning, classifying, predicting, testing, information gathering, sorting (NCMST, 2000).

Literature (Darling-Hammond, 1999; NCMST, 2000; National Research Council, 1997) suggests that high excellent teaching enables learner in gaining a conceptual understanding of concepts. Conceptual understanding of concepts is not possible unless the teacher is trained in exploring and overcoming misconceptions of concepts. According to Shulman (1989), learner comes to classes with many misconceptions so the teacher must have adequate content knowledge to recognize them. According to (Eaton, Anderson & Smith, 1983), teachers should challenge the misconceptions of students and change them with correct scientific explanation. According to (Yip, 1998), the teacher can be a source of misconceptions in students. Stepans (1996) state (as cited in Saccardi,2008) if teacher ignores the students' misconceptions before teaching then he increases the risk of losing the interest of students in concepts and brings them towards memorization instead of understanding.

Along with the role of teacher, we cannot ignore the importance of teaching methods for overcoming misconceptions in concepts. Teaching has different methods in different ages. Socrates introduces the dialectic method and john Dewey introduces project method. According to Javed (2013) in this age of scientific development, new didactical approaches have been introduced and old-style methods with change are also in use to up-date our learners with new knowledge and skill.

Now there is a shift from the behaviorist teaching method to the constructivist teaching method in which students are active in constructing their knowledge with the help of previous knowledge and teacher facilitate this process of learning (National Research Council, 1996). Conceptual change is essential for learning of concepts.

Not all previous knowledge is not helpful in further learning as it may cause hindrance in further learning so, conceptual change is also one of the important aspects for inducing the learning of concepts. New concepts are learned not only by assimilating with earlier ones but also by modifying and even changing existing concepts. From the late 1970s, conceptual change teaching has played a role in improving the learning of science and in overcoming misconceptions of learners in concepts. (Treagust & Duit, 2008). Different models and strategies (Zhou, 2010; Gregoire, 2003; Dole & Sinatra, 1998; Hynd & Al-vermann, 1986) mostly based on Posner et al.'s model is used to facilitate conceptual change. This model is based on four conditions to bring conceptual change which are: 1) dissatisfaction with previous concepts, 2) intelligibility of new concepts 3) plausibility of new concepts and 4) fruitfulness of new concepts. The literature describes conceptual change teaching effective rather than traditional teaching approaches for overcoming misconceptions (Çalik, Okur & Taylor, 2011; Guzetti, Snyder, Glass, & Gamas, 1993; Piquette & Heikkinen, 2005). This kind of teaching takes into account the previous knowledge of students.

Conceptual change teaching has different stages and these include diagnosis or elicitation. In this stage, the teacher uses techniques to diagnose existing concept. Status Change: the teacher uses strategies to diminish problematic knowledge with competing ideas.

Features of Conceptual Change Teaching

Metacognition: there is a need that student must think about their and others ideas and express an opinion about them and change them if wrong? Classroom climate: a good classroom environment that is facilitating for learning is important for conceptual change teaching. Role of Teacher: the teacher should try to make it possible for the learner to express their ideas without fear and help them in building correct ideas. Role of Learner: the learner must take responsibility for their own learning, and help in learning of others (Hewson 1992).

Inquiry Teaching Method

This is a learner-centered teaching method. According to Johnson, (1989) in this method teacher gives direction to students and then they discuss to find a solution to the given assignment. Students take time to find a solution. Role of teacher is passive and he acts as an observer. Due to such environment learners presents their ideas comfortably. This method broadens learner concepts. This method involves the active participation of the teacher and learners. Lederman proposed the following levels of inquiry (as cited in Shaheen, Mushtaq, Bukhari, 2015)

Exploration

At this stage students explore answers of their questions by creative experiences after teacher instructions.

Direct inquiry

Problem and procedure is given and students come on conclusion by analyzing their problem.

Guided inquiry

The only problem is given and students find their own method to find solution of given problem.

Open-Ended Inquiry

This level of inquiry is the highest level and demands responsibility of students from problem searching to arriving at conclusion.

Inquiry-Based Learning Model (5e Instructional Model)

The sequence of steps designed to bring an understanding of the lesson by the teacher is known as an instructional model. Bybee in 1980 developed 5'Es instructional model. According to Shaheen, Mushtaq, Bukhari (2015), this model is based on a constructivist approach and take into account the current knowledge of students. This model also activates the students' curiosity and creativity. Engage, Explore, Explain, Elaborate and Evaluate are five phases of this model. The Engage phase is designed to bring motivation of the learner with activities designed for this purpose. The Explore phase is related to students' questions and answer to investigate topic under study. The explain phase gives the opportunity to teacher and learner to explain the concept and findings. Elaborate phase brings the application of students' understanding in a different context. Evaluation is the last phase deals with the assessment of students understanding.

Data Analysis

One way ANOVA is used on data of the first phase to find the difference between different groups of the sample. T-test was applied on experimental and control group posttest data to find the difference between their achievements

Statistical Analysis of Phase 1 data to Compare Different Groups

Hypothesis 1: There is no significant difference in conceptual understanding of heat and temperature concepts between different groups of prospective science teachers (B.Ed. (regular), B.Ed. (HONS) and B.Ed. (distance)

Table1. ANOVA Table Showing No Significant Difference between Different Groups

	Sum of Squares	Df	Mean Square	F	Sig.

Between Groups	1.337	2	.668	.364	.696
Within Groups	170.903	93	1.838		
Total	172.240	95			

It is obvious from the table that p-value is greater than.005. So, it is concluded that the null hypothesis is accepted that there is no significant difference exist between means of different groups.

Statistical Analysis of Phase 3 data to compare the experimental group and the control group.

Hypothesis 2: There is no significant difference between a conceptual understanding of the experimental group and control group in concepts of heat and temperature.

Table 2. Showing the Difference Between Experimental Group And Control Group

Variable	Group	N	M	SD	T	P
Marks of Physics	Control	20	4.2000	.95145		
	Experimental	20	5.9000	2.17401	-2.799	.006

It is obvious from the table that t-test was applied to results of Phase 3 to find the difference between the experimental group and control group. A result of t-test rejects this null hypothesis and it is concluded that there is significant difference exist between control group and experimental group.

Table 3. Frequency and percentage of misconceptions in experimental and control group after treatment

Misconceptions identified by concept test on heat		Experimental Group		Control Group	
		Frequency	Percentage	Frequency	Percentage
Q 1	1.Hot objects contain more heat always	0	0	3	20
	2. Cool objects always contain less heat	1	6.67	8	53.33
Q2	1.water cannot be at 0c	0	0	3	20
Q3	1.Some material cannot get cool	0	0	7	46.67
	2. All material cannot come at same temperature in same environment.	0	0	5	33.33
Q4	1.The temperature of water will continue to increase even after boiling point	0	0	7	46.67
Q5	1.Woolen materials can generate heat	0	0	6	40
	2. Woolen materials do not allow to enter cool from them	0	0	7	46.67
Q6	1.When things get cool cooling enter in them	0	0	5	33.33
	2. Things get cool because due to the transfer of heat and cool.	0	0	3	20
Q7	1. When things get cool it is cool that is going in them	0	0	6	40
	2. Things get cool because cool is going in and heat is coming out	0	0	3	20
Q8	1. Heat is related with temperature of material rather than mass of material	1	6.67	5	33.33
Q9	1. Some materials are naturally hot like wood and never absorb cool.	0	0	3	20
	2. Metal can absorb more heat and cool than other materials	0	0	8	53.33

Q10	1.Conduction is both for heat and temperature	0	0	5	33.33
	2. During conduction flow of temperature take place	0	0	3	20
Q11	1.Temperature can be transferred from high temperature to low temperature	0	0	4	26.67
	2. Things cool by transfer of both heat and temperature	0	0	5	33.33
Q12	1. Different things can get an equal increase in temperature if they are equal in amount	1	6.67	3	20
	2. Different things can get an equal increase in temperature if they are heated for equal time	0	0	7	46.67

Discussion

A classroom-based on constructivist teaching gives importance to the construction of knowledge rather than memorization of concepts. Such a learning environment is based on the active participation of the learner. In such a learning environment role of the teacher is to assist their students. In constructivist teaching previous knowledge of students also come in contact with their current learning so it becomes possible to overcome their misconceptions. According to (Feden & Vogel, 2003), due to lack of change in teaching methods of teachers students proceed in school without changing their misconceptions. Researches indicate (Wandersee et al., 1994; Chang, 1999; Tan, 2005) that teachers like students also have misconceptions and can be a source of transferring them to their students. Consequently, it is important for pre-service teachers and in-service teachers to be trained in exploring and overcoming misconceptions of students. It is not possible unless we overcome their misconceptions in training years and give them training in constructivist teaching. In this study prospective teachers were tested through a two-tier test. The results indicate the presence of many misconceptions in prospective teachers. To overcome the misconceptions of students they were taught by 5Es learning cycle and post-tested and compared with a group of students taught by traditional teaching methods. The result of the study supports this method in overcoming misconceptions of students as compared to traditional teaching.

Recommendations

Implications for Teachers

1. Role of teachers is very important in better learning so they must be able to diagnose and overcome misconceptions. They must be trained for discussion, lab activities, and assessment to identify misconceptions. They must be trained to teach for overcoming misconceptions.
2. Teacher education must be designed to train teachers in student-centered and constructivist teaching for overcoming misconceptions.
3. The curriculum of every level must be designed by keeping in view the misconceptions of students' of that level.
4. Textbook writers should address the misconceptions of students while writing books.

Conclusion

Teachers should be considered as a source of misconceptions in their students and special focus should be given during the training of teachers in diagnosing and overcoming their misconceptions.

Traditional instructional methods are ineffective in overcoming students' misconceptions. To overcome misconceptions there is a need for a constructivist teaching approach.

References

American Association for the Advancement of Science.(AAAS, 1993). Benchmarks for science literacy: A Project 2061 report. New York: Oxford University Press.

Andersson, B. (1986). Pupils' explanations of some aspects of chemical reactions. Science education, 70(5), 549-563.

Ausubel, D. P. (1968).Educational psychology: A cognitive view. New York:Holt, Rinehart, and Winston.

Beck, J., Czerniak, C. M., & Lumpe, A. T. (2000). An exploratory study of teachers' beliefs regarding the implementation of constructivism in their classrooms. Journal of Science Teacher Education, 11(4), 323-343.

Bell, R. L., Blair, L. M., Crawford, B. A., & Lederman, N. G. (2003). Just do it? Impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. Journal of Research in Science Teaching, 40(5), 487-509.

Bianchini, J. A., & Solomon, E. M. (2003). Constructing views of science tied to issues of equity and diversity: A study of beginning science teachers. Journal of Research in Science Teaching, 40(1), 53-76.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. J. Chem. Educ, 63(10), 873.

Bybee, R. W. (1997). Achieving scientific literacy: From purposes to practical action. Portsmouth, NH: Heinemann.

Çalık, M., Okur, M., & Taylor, N. (2011). A comparison of different conceptual change pedagogies employed within the topic of "sound propagation". Journal of Science Education and Technology, 20, 729-742. doi:10.1007/s10956-010-9266-z

Carlton, K. (2000). 'Teaching about heat and temperature', Physics Education, 35 (2),101.

Chang. J.Y., (1999), Teachers college students' conceptions about evaporation, condensation, and boiling, Science Education, 83, 511-526.

Creswell, J.W. (2003). Research design – qualitative, quantitative and mixed method approaches (2nd ed.). Thousand Oaks, CA: Sage Publications.

Dantonio, M., & Beisenherz, P. C. (2001). Learning to question, questioning to learn. America: Allyn and Bacon.

Darling-Hammond, L. (2000). Solving the Dilemmas of Teacher Supply, Demand, and Standards: How We Can Ensure a Competent, Caring, and Qualified Teacher for Every Child. National Commission on Teaching & America's Future, Kutztown Distribution Center, PO Box 326, Kutztown, PA 19530-0326.

Hodson, D. (2008). Towards scientific literacy: A teachers' guide to the history, philosophy and sociology of science. Sense Publishers.

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. Educational Psychologist, 33, 109-128.

Eaton, J. F., Anderson, C. W., & Smith, E.L. (1983). When students don't know they don't know. Science and Children, 20(7), 7-9.

Erickson, G. L. (1979). Children's conceptions of heat and temperature. Science Education, 63, 221-230.

Feden, P. D., & Vogel, R. M. (2003). Methods of teaching: Applying cognitive science to promote student learning. McGraw-Hill Humanities, Social Sciences & World Languages.

Gregoire, M. (2003). Is it a challenge or a threat? A dual process model of teachers'cognition and appraisal process during conceptual change. Educational Psychology Review, 15, 147-179. doi:10.1023/A:1023477131081.

Gujjar, A. A. (2013). Evaluation of B. Ed Programme and Comparison of It's Curriculum With Bs Education Professional Area (Doctoral dissertation, University of Peshawar, Peshawar).

Guzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting conceptual change in science: A comparative meta- analysis of instructional interventions from reading education and science education. Reading Research Quarterly, 28, 116-159. doi:10.2307/747886

Harrison A. G., Grayson, D. J., & Treagust, D. F. (1999). Investigating a grade 11 student's evolving conceptions of heat and temperature. Journal of Research in Science Teaching, 36(1), 55-87.

Hewson, P. W. (1992, June). Conceptual change in science teaching and teacher education. In a meeting on "Research and Curriculum Development in Science Teaching," under the auspices of the National Center for Educational Research, Documentation, and Assessment, Ministry for Education and Science, Madrid, Spain.

Hynd, C., & Alvermann, D. E. (1986). The role of refutation text in overcoming difficulty with science concepts. Journal of Reading, 29(5), 440-446.

Javed, T. (2013). A Study Of Effectiveness Of Dimensions Of Learning Model For Science Teaching At Elementary Level (Doctoral dissertation, National University of Modern Languages, Islamabad).

Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm?. Educational technology research and development, 39(3), 5-14.

Jonassen, D. H. (1991).Objectivism versus constructivism: Do we need a new philosophical paradigm? Education Technology Research and Development, 39, 5-14.

Kesidou, S., & Duit, R. (1993). Students' conceptions of the second law of thermodynamics—an interpretive study. Journal of Research in Science Teaching, 30(1), 85-106.

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena. Journal of Research in Science Teaching, 41(5), 432-448.

Lawrenz, F. (1986). Misconceptions of physical science concepts among elementary school teachers. School Science and Mathematics, 86(8), 654-660.

Laws, P., Sokoloff, D., & Thornton, R. (1999). Promoting active learning using the results of physics education research. UniServe Science News, 13, 14-19.

National Commission on Mathematics and Science Teaching. (NCMST, 2000). Before it's too late. Jessup, MD: Education Publications Centre, U.S Department of Education.

National Research Council. (1996). National science education standards. Washington, DC: National Academic Press.

Niaz, M. (2000). A framework to understand students' differentiation between heat energy and temperature and its educational implications. Interchange, 31, 1-20.

Ogunmade, T. O. (2005). The status and quality of secondary science teaching and learning in Lagos State, Nigeria.

Paik, S. H., Cho, B. K., & Go, Y. M. (2007). Korean 4- to 11-year-old student conceptions of heat and temperature.Journal of Research in Science Teaching, 44(2), 284-302.

Piquette, J. S., & Heikkinen, H. W. (2005). Strategies reported used by instructors to address student alternate conceptions in chemical equi-librium. Journal of Research in Science Teaching, 42, 1112-1134. doi:/10.1002/tea.20091

Polland, A., & Tann, S. (1993). Reflective teaching in the learning school: A handbook for the classroom. London: Open University.

Saccardi, K. E. (2008). The Ramifications of Teachers Lack of PCK while Uncovering Student Misconceptions.

Sanger, M. J., & Greenbowe, T. J. (1997).Common student misconceptions in electrochemistry: Galvanic, electrolytic, and concentration cells. Journal of Research in Science Teaching, 34, 377-398.

Shaheen, N., Alam, T., Mushtaq, M., & Bukhari, M. A. (2015). Effects of Inquiry Based Learning on the Performance of students' At Elementary Level in Rawalpindi City: An Experimental Study.Academic Research International, 6(2), 382.

Shulman, L. S. (1986). Those who understand: Knowledge in teaching. Educational Researcher, 15(2), 4-14.

Sozbilir, Mustafa (2003),'A Review of Selected Literature on Students' Misconceptions of Heat andTemperature', Bogazici Univeristy Journal of Education, 20 (1), 25-40.

Tan K.C.D., (2005), Pre-service teachers' conceptions of basic inorganic qualitative analysis, Canadian Journal of Science, Mathematics and Technology Education, 5, 7-20.

Tanahoung, C., Chitaree, R., & Soankwan, C. (2010). Probing thai freshmen science students' conceptions of heat and temperature using open-ended questions: a case study. Eurasian Journal of Physics and Chemistry Education, 2(2), 82-94.

Treagust, D. F., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. Cultural Studies of Science.

Wandersee J.H., Mintzes J.J. and Novak J.D., (1994), Research on alternative conceptions in Science,in D. L. Gabel (Ed.), Handbook of research on science teaching and learning, Macmillan, New York, pp. 177-210.

Weiss, L. (2010). ELL AND NON-ELL STUDENTS'MISCONCEPTIONS ABOUT HEAT AND TEMPERATURE IN MIDDLE SCHOOL (Doctoral dissertation, University of Central Florida Orlando, Florida).

Wiser, M., & Kipman, D. (1988). The Differentiation of Heat and Temperature: An Evaluation of the Effect of Microcomputer Models on Students' Misconceptions.

Yeo, S., & Zadnik, M. (2001). Introductory thermal concept evaluation: Assessing students' understanding. The Physics Teacher, 39(8), 496-504.

Zhou, G. (2010). Conceptual change in science: A process of argumentation. Eurasia Journal of Mathematics, Science & Technology Education, 6, 101-110