Title: Introduction to Science and Mathematics Education Research

Credits: 4 (~44 hours, about 2 contact session per week of 2 hours each)

Instructors: K K Mashood, Shweta Naik

Semester 2: January to May, 2021

Objectives of the Course:

1. Understand broadly the motivation and rationale for research in science, technology and mathematics education (STME)
2. Introduction to research literature in science, technology and mathematics education
3. Exposure to research in science, technology and mathematics education at HBCSE
4. Introduction to some of the key themes and issues in science, technology and mathematics education research

Learning goals:

- Foster ability to search and identify research materials in STME (journal articles, book chapters etc.)
- Develop capacity to critically read and analyse research papers in STME
- Inculcate capacity to discuss, engage in argumentation and make presentations of research papers in STME
- Develop familiarity with key threads and themes in STME research and identify ones own areas of interest
- Cultivate ability to summarise arguments of research articles and eventually conduct literature reviews on chosen themes/topics in STME

Class Structure and Assessments:

The course will cover nine key themes in STME, which are mentioned below. Around two to three sessions will be devoted for discussing papers selected from each of the themes. Each session will discuss one paper and the crediting students will take turns in presenting the paper and leading the discussion. The auditing students can volunteer to present, but is not mandatory. In addition to the papers chosen for discussion in a session, instructors may assign background readings at instances where they deem it relevant. The presentation and discussion have to be structured in such a way that maximum participation from all the participants is ensured and thereby discussion among them is enabled.

Assessment will be based on the following accounts:

1) Presentation of papers

2) Participation in discussion

3) Two term papers - a mid term and a final term paper. The topic of mid-term paper will be assigned by the instructors and the expected length is around 2000 words. It will have half the weightage in score compared to the final term paper, whose expected length is 4000 -5000 words . For the final term paper students can choose a theme, in consultation with instructors, that they are interested in and is likely to work in future.

Readings:

Introductory Session:

- Anderson, C. (2007). Perspectives on science learning. In S. Abell & N. Lederman (Eds.). Handbook of Research on Science Education, pp.330. Taylor & Francis.

Theme 1: Education and Society

1. Greer, B. (2011). What is Mathematics Education for? In K. Subramaniam & A. Majumdar (Eds.) epiSTEME 3 – *Proceedings of the International Conference to Review Research in Science, Technology and Mathematics Education*. MacMillan.
2. Raina, D. (2011). Institutions and Knowledge: Framing the Translation of Science in Colonial South Asia. *Asiatische Studien/Etudes Asiatiques, 65(4), 945-967.*
3. Rampal, A. (2008). Scaffolded participation of children: perspectives from India. *The International Journal of Children's Rights, 16(3), 313-325.*
4. Hodson, D. (2003) Time for action: Science education for an alternative future. *International Journal of Science Education,* Vol.25, Issue 6. pages 645-670.
5. K. Krishna (2010). Culture, state and girls: An educational perspective. *Economic and Political Weekly,* Vol 45, Issue No. 17, April 24, 2010.
6. Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. Journal of experimental social psychology, 35(1), 4-28.

Theme 2: Out-of-school and connections to real world

1. Allchin, D. (1999). *Values in Science: An educational perspective, Science & Education*, 8, 1-12.
2. Braund, M. & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out‐of‐school learning, *International Journal of Science Education*, 28(12), 1373-1388.
3. Raveendran, A., & Chunawala, S. (2015). Values in science: making sense of biology doctoral students' critical examination of a deterministic claim in a media article. *Science Education*, *99*(4), 669-695.
4. Date, G., & Chandrasekharan, S. (2018). Beyond efficiency: Engineering for sustainability requires solving for pattern. *Engineering Studies*, *10*(1), 12-37.
5. Rennie, L. (2007). Learning science outside of school. In S. Abell & N. Lederman (Eds.). Handbook of Research on Science Education, pp. 125-167, Taylor & Francis.
6. Skovsmose, O., & Valero, P. (2008). Democratic access to powerful mathematical ideas. *Handbook of international research in mathematics education*, 415.

Theme 3: Teacher Education

1. Batra, P. (2013). Teacher Education and Classroom Practice in India: A Critique and Propositions. In S. Chunawala & M. Kharatmal (Eds.) *The epiSTEME Reviews – Research Trends in Science, Technology and Mathematics Education*, Volume 4. India: Narosa.
2. Brown, P., Friedrichsen, P., & Abell, S. (2013). The development of prospective secondary biology teachers' PCK. *Journal of Science Teacher Education*, 24(1), 133-155.
3. Crippen, K. J. (2012). Argument as professional development: Impacting teacher knowledge and beliefs about science. *Journal of Science Teacher Education*, 23(8), 847-866.
4. Kumar, R. S., Subramaniam, K., & Naik, S. S. (2017). Teachers' construction of meanings of signed quantities and integer operation. *Journal of Mathematics Teacher Education*, *20*(6), 557-590.
5. Loewenberg Ball, D., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of teacher education*, 60(5), 497-511.
6. Lumpe, A., Czerniak, C., Haney, J., & Beltyukova, S. (2012). Beliefs about teaching science: The relationship between elementary teachers' participation in professional development and student achievement. *International journal of science education*, 34(2), 153-166.
7. Stigler, J. W., & Hiebert, J. (2009). The teaching gap: Best ideas from the world's teachers for improving education in the classroom. Simon and Schuster.

Theme 4: Classroom Interaction and Assessment

1. Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher*, 30(3), 141-158.
2. Jones, A. (2012). Technology in Science Education: Context, Contestation and Connection, In B. Fraser, K. Tobin & C. McRobbie (Eds.), *Second International Handbook of Science Education*, Part 1, pp. 811-822. Springer
3. Mashood, K. K., & Singh, V. A. (2012). An inventory on rotational kinematics of a particle: unravelling misconceptions and pitfalls in reasoning. *European Journal of Physics*, *33*(5), 1301.
4. Larson, J. (1995). Fatima's Rules and Other Elements of an Unintended Chemistry Curriculum. Paper presented at American Education Research Association (AERA), San Francisco
5. Ramadas, J. & Kulkarni, V. (1982). Pupil participation and curriculum relevance, *Journal of Research in Science Teaching*, 19 (5), 357-365, 1982
6. Russ, R.S., Lee, V.R. and Sherin, B.L., 2012. Framing in cognitive clinical interviews about intuitive science knowledge: *Dynamic student understandings of the discourse interaction*. Science Education, 96(4), pp.573-599.

Theme 5: Student Conceptions Studies

1. Smith III, J. P., DiSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. The journal of the learning sciences, 3(2), 115-163.

2. Ara, F., Chunawala, S., & Natarajan, C. (2011). A study investigating Indian middle school students' ideas of design and designers. *Design and Technology Education: an International Journal*, *16*(3).

3. Eilks, I., Moellering, J., Valanides, N. (2007) Seventh-grade students' understanding of chemical reactions: Reflections from an action research interview study. Eurasia Journal of Mathematics, Science & Technology Education, 2007, 3(4), 271-286

4. Subramaniam K. and Padalkar S. Visualisation and Reasoning in Explaining the Phases of the Moon, International Journal of Science Education (2009), 31(3): 395-417

5. Sudhir Panse, Jayashree Ramdas and Arvind Kumar Alternative Conceptions in Galilean relativity: frames of reference International Journal of Science Education (1994), 16 (1): 63-82

6. Hammer, D. (1996). Misconceptions or p-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions. *The journal of the learning sciences*, *5*(2), 97-127.

Theme 6: Epistemology and Science Education Research

1. Hutchison, P., & Hammer, D. (2010). Attending to student epistemological framing in a science classroom. *Science Education*, *94*(3), 506-524.

2. Elby, A., & Hammer, D. (2010). Epistemological resources and framing: A cognitive framework for helping teachers interpret and respond to their students' epistemologies. *Personal epistemology in the classroom: Theory, research, and implications for practice*, *4*(1), 409-434.

3. Sirnoorkar, A., Mazumdar, A., & Kumar, A. (2020). Towards a content-based epistemic measure in physics. *Physical Review Physics Education Research*, *16*(1), 010103.

4. Odden, T. O. B., & Russ, R. S. (2018). Sensemaking epistemic game: A model of student sensemaking processes in introductory physics. *Physical Review Physics Education Research*, *14*(2), 020122.

5. Gupta, A., & Elby, A. (2011). Beyond epistemological deficits: Dynamic explanations of engineering students' difficulties with mathematical sense-making. *International Journal of Science Education*, *33*(18), 2463-2488.

6. Chen, Y., Irving, P. W., & Sayre, E. C. (2013). Epistemic game for answer making in learning about hydrostatics. *Physical Review Special Topics-Physics Education Research*, *9*(1), 010108.

7. Singh, G., Shaikh, R., & Haydock, K. (2019). Understanding student questioning. *Cultural Studies of Science Education*, *14*(3), 643-697.

Theme 7: Modelling and Representations in Science Education

1. Hestenes, D. (2006). Notes for a modeling theory. In Proceedings of the 2006 GIREP conference: Modeling in physics and physics education (Vol. 31, p. 27). Amsterdam: University of Amsterdam.

2. Pande, P., & Chandrasekharan, S. (2017). Representational competence: towards a distributed and embodied cognition account. *Studies in Science Education*, *53*(1), 1-43.

3. Chiu, M. H., & Lin, J. W. (2019). Modeling competence in science education. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1-11.

4. Brewe, E., 2008. Modeling theory applied: Modeling Instruction in introductory physics. American Journal of Physics, 76(12), pp.1155-1160.

5. Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. *Handbook of child psychology and developmental science* , 1-44.

6. Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. The cognitive basis of science, 133-153.

7. Karnam, D., Mashood, K. K., & Sule, A. (2020). Do student difficulties with vectors emerge partly from the limitations of static textbook media?. *European Journal of Physics*, *41*(3), 035703.

Theme 8: Conceptual Change

1. diSessa, A. A. (2006). A History of Conceptual Change Research: Threads and Fault Lines. In R. K. Sawyer (Ed.), The Cambridge handbook of: The learning sciences (pp. 265-281). New York, NY, US: Cambridge University Press.

2. Vosniadou, S. (2012). Reframing the Classical Approach to Conceptual Change: Preconceptions, Misconceptions and Synthetic Models, In B. Fraser, K. Tobin & C. McRobbie (Eds.), Second International Handbook of Science Education, Part 1, pp. 119-130. Springer.

3. Chi, M.T.H. (2008). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), Handbook of research on conceptual change (pp. 61-82) . Hillsdale, NJ: Erlbaum.

4. Nersessian, N. J., & Chandrasekharan, S. (2009). Hybrid analogies in conceptual innovation in science. *Cognitive Systems Research*, *10*(3), 178-188.

5. Duit R. & Treagust D. (2012) : How can conceptual change contribute to theory and practice in science education ? In B. Fraser, K. Tobin & C. McRobbie (Eds.), Second International Handbook of Science Education, P art 1, p p. 107-118. Springer.

6. Chi, M. T., & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In *Reconsidering conceptual change: Issues in theory and practice* (pp. 3-27). Springer, Dordrecht.

Theme 9: Ontology and Science Education Research

1. Chi, M. T., Roscoe, R. D., Slotta, J. D., Roy, M., & Chase, C. C. (2012). Misconceived causal explanations for emergent processes. *Cognitive science*, *36*(1), 1-61.

2. Dreyfus, B. W., Gupta, A., & Redish, E. F. (2015). Applying conceptual blending to model coordinated use of multiple ontological metaphors. *International Journal of Science Education*, *37*(5-6), 812-838.

3. Slotta, J. D., & Chi, M. T. (2006). Helping students understand challenging topics in science through ontology training. *Cognition and instruction*, *24*(2), 261-289.

4. Gupta, A., Hammer, D., & Redish, E. F. (2010). The case for dynamic models of learners' ontologies in physics. *The Journal of the Learning Sciences*, *19*(3), 285-321.

5. Chi, M. T., & Slotta, J. D. (1993). The ontological coherence of intuitive physics. *Cognition and instruction*, *10*(2-3), 249-260.

6. Jacobson, M. J., Kapur, M., So, H. J., & Lee, J. (2011). The ontologies of complexity and learning about complex systems. *Instructional Science*, *39*(5), 763-783.