Title: Introduction to Science and Mathematics Education Research

Course Number: SCE101.2

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

Instructors: Mashood KK, Shweta Naik

Semester 1: August to December, 2025

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 the capacity to read and analyze research papers in STME critically
- 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 one's own areas of interest
- Cultivate the ability to summarize arguments of research articles and eventually conduct literature reviews on chosen themes/topics in STME

Class Structure and Assessments:

The course will cover 11 key themes in STME, which are mentioned below. About two sessions will be devoted to 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 it 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. Bishop, A. J., & Forgasz, H. (2007). Issues in access and equity in mathematics education. In *Second Handbook of Research on Mathematics Teaching and Learning* (pp. 1145-1167). National Council of Teachers of Mathematics.
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. Bourdieu, P., Passeron, J. C., & Nice, R. (1977). Education, society and culture. Trans. Richard Nice. London: SAGE Publications, 15-29. (Chapter 1: Cultural Capital and Pedagogic Communication)
4. Rampal, A. (2008). Scaffolded participation of children: perspectives from India. *The International Journal of Children's Rights, 16(3), 313-325.*
5. K. Krishna (2010). Culture, state and girls: An educational perspective. *Economic and Political Weekly,* Vol 45, Issue No. 17, April 24, 2010.
6. D'Ambrosio, U. (1990). The role of mathematics education in building a democratic and just society. For the learning of mathematics, 10(3), 20-23

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. Boaler, J. (1993). Encouraging the transfer of 'school mathematics to the 'real world through the integration of process and content, context and culture. *Educational Studies in Mathematics*, 25(4), 341-373.
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 patterns. *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.
7. Bose, A., & Subramaniam, K. (2013). Characterising work-contexts from a mathematics learning perspective. In Proceedings of epiSTEME-5: Third international conference to review research on science, technology and mathematics education (pp. 173-179).

Theme 3: Teacher Education

1. Batra, P. (2005). Voice and agency of teachers: Missing link in national curriculum framework 2005. Economic and Political Weekly, 4347-4356.
2. Lerman, S. (2001). A review of research perspectives on mathematics teacher education. Making sense of mathematics teacher education, 33-52.
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

Theme 5: Developing Theories in Science and Mathematics Education

1. Guru, G., & Sarukkai, S. (2018). The cracked mirror: An Indian debate on experience and theory. Oxford University Press. (Chapter 2: Experience and Theory: From Habermas to Gopal Guru - Sundar Sarukkai)
2. Silver, E. A., & Herbst, P. (2007). Theory in mathematics education scholarship. Second handbook of research on mathematics teaching and learning, 1, 39-67.

Theme 6: 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 7: 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. Boucher, S. C., & Forbes, C. (2024). The pragmatic turn in the scientific realism debate. *Synthese*, *203*(4), 111.

3. 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.

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

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.

Theme 8: 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. Salve, J., Upadhyay, P., Mashood, K. K., & Chandrasekharan, S. (2024). Performative Bundles: How Teaching Narratives and Academic Language Build Mental Models of Mechanisms. *Science & Education*, 1-39.

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

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

5. 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 9: 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.

Theme 10: Conceptual Blending and Science Education Research

1. Chapters 1-3, Fauconnier, G., & Turner, M. (2008). *The way we think: Conceptual blending and the mind's hidden complexities*. Basic books.

2. Fauconnier, G., & Turner, M. (1998). Conceptual integration networks. *Cognitive Science*, 22(2), 133-187. https://markturner.org/cinLEA.pdf

3. Van den Eynde, S., Schermerhorn, B. P., Deprez, J., Goedhart, M., Thompson, J. R., & De Cock, M. (2020). Dynamic conceptual blending analysis to model student reasoning processes while integrating mathematics and physics: A case study in the context of the heat equation. *Physical Review Physics Education Research*, *16*(1), 010114.

4. Hutchins, E. (2005). Material anchors for conceptual blends. *Journal of pragmatics*, *37*(10), 1555-1577.

5. Al-Zahrani, A. (2007). Darwin's metaphors revisited: Conceptual metaphors, conceptual blends, and idealized cognitive models in the theory of evolution. *Metaphor and Symbol*, *23*(1), 50-82.

Theme 11: On Sustainability, Identity, Cultural Reproduction etc.

1. Dutta, D., & Chandrasekharan, S. (2021). Solving for pattern: An ecological approach to reshape the human building instinct. *Environmental Values*, *30*(1), 65-92.

2. Bonnett, M. (2013). Normalizing catastrophe: Sustainability and scientism. *Environmental Education Research*, *19*(2), 187-197.

3. Derrida, J. (2020). *Deconstruction in a nutshell: A conversation with Jacques Derrida, with a new introduction*. Fordham University Press.

4. Date, G., & Chandrasekharan, S. (2018). Beyond efficiency: Engineering for sustainability requires solving for pattern. *Engineering Studies*, *10*(1), 12-37.

5. Gee, J. P. (2000). Chapter 3: Identity as an analytic lens for research in education. *Review of research in education*, *25*(1), 99-125.

6. Nash, R. (1990). Bourdieu on education and social and cultural reproduction. *British journal of sociology of education*, *11*(4), 431-447.