Philosophy of education for sustainable development in mathematics education: have we got one?

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Abstract: *Over the past few decades, the aspect that emphasizes a focus on sustainable development to transform education is not new. It has been seen that education systems around the world have taken action to integrate Education for Sustainable Development (ESD) as part of their responsibility. While recent studies have offered a wealth of empirical evidence about the benefits of ESD, research has argued that sustainable development and mathematics education remain largely unconnected in actual classrooms. In addition, the ideas of sustainable development in the curriculum have been defined in a variety of different way across different subject areas. The question about what ESD in mathematics education could look like at school remain unanswered. Thus, in this paper, we present a theoretical synthesis of the specialized literature in the learning and teaching of mathematics in relation to sustainable development. In doing so, we attempt to call attention to the need for a philosophy of ESD in mathematics education.*

INTRODUCTION

The aspect that emphasizes a focus on sustainable development to transform education is not new. In recent years, Education for Sustainable Development (ESD) has been the term used internationally and by the United Nations. ESD has its origins in the UN Decade of Education for Sustainable Development 2005-2014. Over the past few decades, the ideas of integrating ESD across all subjects in the primary and secondary curriculum has led to different terms and concepts being used to express the importance of the sustainable development of children learning. Like the terms "sustainable development" or "sustainability", often appear interchangeably in the literature, sometimes even said to be synonymous.

Differences in the nature of "sustainable development" and "sustainability" have also been noted by several researchers. For example, the Bruntland Commission Report (World Commission on Environment and Development, 1987) noted that "sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". By contrast, Jeronen (2013) that "sustainability is a paradigm for thinking about the future in which environmental, societal and economic considerations are balanced in the pursuit of an improved quality of life" (p. 2371). Diesendorf (2000) considered that sustainability is "as the goal or endpoint of a process called sustainable development" (p. 35). Nowadays, we have seen that as stated by Petocz (2003), "academics in a wide range of subject areas (including mathematics) understand the ideas of sustainability in the curriculum in a variety of different ways" (p. 137). Various models have been developed and implemented DES to meet specific instructional goals or subjects (Tilbury, Reid, & Podger, 2003).

Over the past few decades, in order to respond to the UN's call for ESD, education systems around the world have taken action to integrate Education for Sustainable Development (ESD) as part of their responsibility. For example, Sustainability as a cross-curricular priority was introduced to the Australian Curriculum in 2010. In Scotland, "Learning for Sustainability" has been embedded in school policy since 2012. However, recent research shows that there has been limited progress in ESD in actual classrooms (Bamber et al., 2016; Hunt et al., 2011; Laurie et al., 2016; Summers, 2013). Specifically, in a subject area such as mathematics, "it seems difficult to conceive of how this could be done" (Petocz & Reid, 2003, p.136). Renert (2011, p.20) argued that "sustainability and mathematics education remain largely unconnected in the research literature". A question arises as to how to define and promote sustainability in mathematics education remains unanswered. Given that mathematics is the dorsal spine of modern civilization (D'Ambrosio, 2007) and that mathematics plays the essential role in STEM (Science, Technology, Engineering, and Mathematics) education (National Council of Teachers of Mathematics, 2014), integrating ESD in mathematics education is particularly important in this time and age. In this paper, we therefore reviewed ESD-related research in mathematics education and shared our thoughts on mathematics teaching and learning in relation to ESD.

PHILOSOPHY OF ESD IN MATHEMATICS EDUCATION: HAVE WE GOT ONE?

Renert (2011) noted that Platonism had a significant impact on the philosophy of early mathematics education in that children learned mathematics as consisting of abstract mathematical objects with no or little causal properties connecting to their environment. Platonism ruled out social dimensions in mathematics teaching and learning, which has been questioned by social constructivists. As Ernest (2018) argued, children will not develop the social meaning of important symbol systems and the ways to use them if they are not provided with a social situation of development. Constructivist perspectives on learning and teaching have been a popular topic among mathematics educators, psychologists and researchers (e.g. Cobb & Bauersfeld, 1995) and as a result, have contributed to shaping mathematics reform efforts in many countries around the world (e.g. Ministry of Education in Taiwan, 1993).

Skovsmose (2016) considered the philosophy of mathematics education from the perspective of critical mathematics education and emphasized the importance of "reading and writing the world with mathematics" (p. 2). Skovsmose (1994) argued that mathematics is used to model and solve problems and consequently, "we not only 'see' according to mathematics, we also 'do' according to mathematics" (p. 55). Skovsmose's perspective offered implications for how mathematics can constitute social reality in that "the mode of thought [was] used to facilitate reasoning, and this type of abstraction is exemplified by mathematical concepts and mathematical modelling" (p. 51).

While the number of studies on ESD in mathematics education is small, a few studies have been conducted to respond to the call for ESD. For instance, Renert considered that ESD in mathematics education (what he calls sustainable mathematics education) is to see mathematics for life. Examples discuss by Renert (2011) included chaos theory and fractal geometry in that students can be introduced to connect mathematics education with the environment. Although the mathematical detail in Chaos and fractals may be far beyond the level of high school mathematics, students can have an opportunity to learn the nonlinear dynamic patterns of living systems broadly. Barwell (2018) also stressed that it is important to provide opportunities for students to gain insight into the role of mathematics in their lives and consequently, drawing their attention to real world issues such as the climate change in the Earth's ecosystem.

It is also important to note that equity and social justice are core elements of ESD, as it aims to empower "learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity" (UNESCO, 2014, p. 12). However, it has been argued that as criticized by Millroy (1992), "academic mathematics education has failed for the majority of the people. This failure is due in part to the conventional portrayal of mathematics as a prized body of knowledge that is the property of an elite group of people" (p. 50).

Larnell, Bullock, and Jett (2016) called toward rethinking teaching and learning mathematics for social justice from a critical race perspective. The issues of equity and justice have provided a foundation for the development of ethnomathematics (D'Ambrosio, 1985; Naresh & Kasmer, 2018). Drawing on the ethnomathmatics perspectives, Naresh and Kasmer (2018) discussed two activities for prospective teachers to learn how to teach geometry by using cultural artifacts and by a sociocultural art form in that the prospective teachers were required to engage in a "two-way dialogue in which knowledge and their associated values are brought into the open for scrutiny" (Civil, 2002, p. 146).

In addition, the constructs of a culturally responsive mathematics education (CRME) have also suggested that teachers and the young generation need to think globally and have international perspective to incorporate a global dimension into teaching and learning (Heyl & McCarthy, p. 3). As stressed by Mukhopadhyay et al. (2009), it is important for teachers to create a culturally responsive mathematics teaching to empower their students' development of mathematical knowledge in mathematics classrooms.

Another key feature of ESD is its emphasis on students' engagement in interdisciplinary activities and discussion about their learning (Barwell, 2018). While the importance of interdisciplinary teaching and learning has been increasingly recognized, the complexities of interdisciplinary approaches in mathematics education continue to pose challenges for mathematics teachers to work with others across traditional disciplinary boundaries (Roth, 2014). In the interest of incorporating interdisciplinary teaching and learning in teacher education, we conducted workshops for mathematics and geography teachers to jointly create lesson plans for developing students' data literacy skills by using census data to explore urban inequalities. We have also conducted workshops for mathematics, science, design and technology, and art teachers to collaborate together and develop an enrichment activity for students to explore the connection between Fibonacci spiral and Nautilus shells.

In line with Roth (2014), we also found that "when as a result of interdisciplinary projects, mathematics teachers no longer find their mathematics just as other specialist teachers no longer find sufficient attention to their discipline in joint projects" (p. 318). Teachers often raised concerns over the effectiveness of interdisciplinary teaching on their students' mathematical attainment. Indeed, over the past two decades, the "teaching to the test'' phenomenon has greatly impacted on mathematics education, which made mathematics teaching strongly academically oriented (Tsai & Li, 2017). It is therefore important to consider that as Schoenfeld (1992) stated, "goals for mathematics instruction depend on one's conceptualization of what mathematics is, and what it means to understand mathematics" (p. 343). Admittedly, achieving interdisciplinary approach in mathematics require us to rethink, re-envision mathematics teaching and learning for 21st century learning priorities.

We therefore argue that it is still unclear what ESD in mathematics could look like in the curriculum. Moreover, as we mentioned earlier, there has been a research gap in the philosophy for ESD in mathematics. In line with Gellert (2011), we also believe:

thinking of mathematics only as a powerful tool for solving economic problems is a truncated conception of mathematics-in-society […] If the call for a sustainable mathematics education includes a critical questioning of the relationship between mathematics, technology and society, and if it does not reduce mathematics to a remedy and an answer, then this mathematics education has the potential to break with many myths about mathematics and to reconcile the mathematics educator's task with the desire to act in an ecologically sustainable way (p. 20).

CONCLUSION

It is worth mentioning here that when searching literature in this particular area, we noticed that while "science education is shown to fit in very well with the tenets of education for sustainable development" (Akpan, p. 493], there has been little research in ESD in mathematics education over the past few decades (Barwell, 2018). Furthermore, despite increasing awareness of the importance of sustainability, there has been no clear rationale for ESD in mathematics education. In this paper, we attempt to call attention to the the need for a philosophy of ESD in mathematics education, since ESD in mathematics education requirws a new philosophy "for thinking and acting about how we can reorient mathematics towards environmentally and socially conscious thinking to engage the young generation in ethical action for a better future" (Li & Tsai, in press). Washington (2019) has also pointed out that we need to reform the curriculum to allow students to take an ethical action toward nature, ecological economics, civics, and culture philosophy. Undoubtedly, there is certainly still much work to be done and this paper may only be one amongst several attempts to achieve this goal. Ongoing research into the philosophy of ESD in mathematics education will no doubt contribute further to an understanding of this highly complex and demanding area of education.

References

Bamber, P., Bullivant, A., Glover, A., King, B., &McCann, G. (2016). A comparative review of policy and practice for education for sustainable development/education for global citizenship (ESD/GC) in teacher education across the four nations of the UK. *Management in Education*, 30(3), 1–9.

Barwell, R. (2018). Some thoughts on a mathematics education for environmental sustainability. In P. Ernest (Ed), *The philosophy of mathematics education today - ICME-13 Monographs* (pp.145-160). Switzerland: Springer International Publishing.

Civil, M. (2002). Culture and mathematics: A community approach. *Journal of Intercultural Studies*, 23(2), 133–148.

Cobb, P., & Bauersfeld, H. (1995). The emergence of mathematical meaning: interaction in classroom cultures. Hillsdale, NJ: Lawrence Erlbaum Associates.

D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics*, 5(1), 44–48.

D'Ambrosio, U. (2007). The role of mathematics in educational systems. *ZDM-International Journal on Mathematics Education*, 39, 173–181.

Ernest, P. (2018). *The philosophy of mathematics education today - ICME-13 Monographs* (pp.13-38). Switzerland: Springer International Publishing.

Gellert, U. (2011). Now it concerns us! A reaction to sustainable mathematics education. *For the Learning of Mathematics*, 31 (2), 19-20.

Hunt, F., Chung, L.T., & Rogers, M. (2011). Taking stock: A report from the UK teacher education network for sustainable development (ESD)/global citizenship (GC) – survey on provision for ESD/GC in initial teacher education in the UK. London: CCCI/LSBU. Available at: http://se-ed.co.uk/edu/wp-content/uploads/2014/03/taking_stock-July-2011.pdf.

Heyl, J., & McCarthy, J. (2003). *International education and teacher preparation in the U.S.* Paper presented at the conference on global challenges and U.S. higher education: National needs and policy implications. Duke University, Durham, NC.

Jeronen E. (2013) Sustainability and Sustainable Development. In: Idowu S.O., Capaldi N., Zu L., Gupta A.D. (eds) *Encyclopedia of Corporate Social Responsibility*. Berlin, Heidelberg: Springer.

Larnell, G., Bullock, E., & Jett, C. (2016). Rethinking teaching and learning mathematics for social justice from a critical race perspective. *Journal of Education*, 196(1), 19–30.

Laurie, R., Nonoyama-Tarumi, Y., McKeown, R., & Hopkins, C. (2016). Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *Journal of Education for Sustainable Development*, 10(2), 226-242.

Mukhopadhyay, S., Powell, A. B., & Frankenstein, M. (2009). An ethnomathematical perspective on culturally responsive mathematics education. In B. Greer & S. Mukhopadhyay (Eds.), *Culturally responsive mathematics education* (pp. 65–84). Mahwah, NJ: Roultledge.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: NCTM

Petocz, P., & Reid, A. (2003). What on earth is sustainability in mathematics education? *New Zealand Journal of Mathematics*, 32, 135-144.

Renert, M. (2011). Mathematics for life: sustainable mathematics education. *For the Learning of Mathematics,* 31(1), 20-26.

Roth. W. M. (2014) Interdisciplinary approaches in mathematics education. In: Lerman S. (ed) *Encyclopedia of Mathematics Education*. Dordrecht: Springer.

Schoenfeld, A. H. (1992). Learning to think mathematically: problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for research on mathematics teaching and learning* (pp. 334-370). New York: MacMillan.

Skovsmose, O. (2016). What could critical mathematics education mean for different groups of students?, For the Learning of Mathematics, 36(1), 2-7.

Summers, D. (2013). Education for sustainable development in initial teacher education: From compliance to commitment—sowing the seeds of change, *Journal of Education for Sustainable Development*, 7(2), 205-222.

Tilbury, D., Reid, A., & Podger, D. (2003). *Action research for university staff: changing curricula and graduate skills towards sustainability*, Stage 1 Report prepared for Environment Australia.

Tsai, T.L. & Li, H.C. (2017). International comparative studies in mathematics education: are we obsessed with the international rankings of measured educational outcomes? *International Journal of Mathematical Education in Science and Technology, 48*(8), 1262-1267.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2012). Shaping the education of tomorrow: 2012 report on the UN Decade of Education for Sustainable Development (Abridged). Available at: http://unesdoc.unesco.org/images/0021/002166/216606e.pdf .

UNESCO. (2014). Roadmap for implementing the global action programme for education for sustainable development. Available at: https://sustainabledevelopment.un.org/content/documents/1674unescoroadmap.pdf.

Washington, H. (2019). Dialogue for a sustainable economy. Presentation at the conference on Dialogue for sustainable economy. Centre for the advancement of the steady state economy: Sydney.

World Commission on Environment and Development (1987). Report of the world commission on environment and development: our common future, Oxford: Oxford University Press.