DOI: https://doi.org/10.15625/2615-8957/22210104

Developing a culturally relevant mathematics curriculum using transdisciplinary approaches

Catherine P. Vistro-Yu
cvistro-yu@ateneo.edu
Ateneo de Manila University
(PHILIPPINES)

ABSTRACT: *One of the articulated values of mathematics education in the Philippines is cultural rootedness. It refers to one's appreciation of the value of mathematics in a community that includes the origins of mathematics in one's culture, its rich history, evolution, and development. For students to capture the multi-faceted nature of mathematics and appreciate its relevance in their lives, different aspects of mathematics should be considered separately and perhaps, taught independently in schools. The cultural-historical dimension of mathematics is one such aspect. In this presentation, some initiatives in producing culturally and historically relevant mathematics lessons for primary and secondary schools in the Philippines will be shared. To expand these mathematics curriculum innovations, transdisciplinarity as an alternative perspective and approach is considered and applied in the context of an art movement in Manila. Recommendations to help sustain similar curriculum innovations in schools will be offered.*

KEYWORDS: **cultural value of mathematics, school mathematics curriculum, nature of mathematics, transdisciplinarity, curriculum innovation**

Received 15/10/2021 Revised manuscript received 10/03/2022 Published 30/03/2022.

1. Why mathematics in schools?

Perhaps one of the biggest shortcomings of school mathematics curricula is its assumption that all students need to learn the same mathematics no matter what their preparation or interests in future careers are. With teachers practically *"forcing mathematics down their throats"* year in and year out, students' negative feelings are hardly unexpected – utter dislike, fear, and continued disinterest in the subject. Why must mathematics be learned in schools? Why should we teach mathematics in schools?

In a paper delivered in celebration of the 100-year anniversary of L'Enseignement Mathématique, the official organ of the International Commission on Mathematical Instruction (ICMI), a sub-commission of the International Mathematical Union (IMU), D'Ambrosio (2000) noted that over the hundred years of IMU's and later ICMI's existence, the objectives of teaching mathematics have been overlooked. For him, curriculum consists of the why, the what, and the how. D'Ambrosio argued that conferences on mathematics education, such as the ICME series almost always attempt to answer the questions of what mathematics to teach in schools and how to teach the agreed upon contents of mathematics. He cited that the Modern Mathematics movement anchored upon advances in the cognitive sciences, calculations, and data retrieval, brought in new contents and methods in mathematics education. Yet, the question of why we teach mathematics remained unanswered. He declared:

> *"However, the objectives of mathematics education were unclear. And they remain so. The rhetoric of personal and social advances is not clearly focused, and exclusion seems to be the most noticeable effect of mathematics education. The question "Why teach mathematics?" seems to be the crux." ~*
> (D'Ambrosio, 2000, p.310)

Not knowing why mathematics must be taught in schools inevitably leads one to disengage from the subject and be isolated from it. Not knowing the purpose of mathematics eventually blurs the path through which it is meant to help sharpen students' mental abilities. Perhaps, in attending to this most important question, students will be able to draw from deep within themselves and ask why mathematics is important, how it is connected to their world, and why it is relevant in their lives as they make sense of what

mathematics is.

In its Call for Papers, organizers of TSG 25 at the 11th International Congress on Mathematical Education 2008, gave a convincing argument:

"Mathematics is a fundamental part of human thought and logic, and integral to attempts at understanding the world and ourselves. Mathematics provides an effective way of building mental discipline and encourages logical reasoning and mental rigor. In addition, mathematical knowledge plays a crucial role in understanding the contents of other school subjects such as science, social studies, and even music and art." (Park & Brombacher, 2008)

This speaks volumes about the value of mathematics in schools. Consistent with the last sentence of the above quote, the Philippine Mathematics Framework for Basic Education espouses cultural rootedness as one of the values of mathematics education in the Philippines.

2. The missing mathematics in schools

Secondary school students complain that they cannot see the value of mathematics beyond computations and measurements unless they become STEM majors in university (Brown, Brown, & Bibby, 2008; Murray, 2011; Pradel, 2019; Pradel & Vistro-Yu, 2021). Prior to a four-day lesson for a research study by Pradel (2019) on the use of mathematical modeling to teach sinusoidal functions, Grade 11 students in an all-male private school in the Philippines articulated a limited conception of mathematics in the world. They believed that simple applications of fundamental arithmetic are the only mathematical tools one needs for handling day-to-day tasks and activities. Any mathematics learned in higher grade levels, thus, has little value unless one chooses a career in the scientific or engineering disciplines. It is in this context that a fresh look at the contents of the school mathematics curriculum is called for.

Certainly, there is more to learning functions, graphs, and sequences than mere manipulations and drawings. For students who are interested in fields other than STEM, however, these mathematical topics have little or no concern in their lives or chosen career-paths. Not all students -- in fact only a few -- will ever go into science, engineering, or math-heavy careers. More importantly, there are students who are prepared for higher levels of mathematics instruction while there are those who have not learned deeply enough to move further in their education. Hence, streaming or tracking has become a default curriculum model beginning in Junior High School (e.g., Singapore) or in Grade 11 (e.g., Philippines). Such a model helps as mathematics courses offered in the different tracks exemplify a wide variety of mathematical applications and uses. However, many of these applications are often rigid, unrealistic, and portray embellished situations that simply use basic mathematical concepts. Thus, even with streaming, mathematics continues to be pushed away and is undesired by many.

As a mathematics educator, I am particularly saddened that the mathematics curriculum in schools is narrow, limited and fails to capture the multi-faceted nature of mathematics (Ziegler and Loos, 2017). This naturally results in students' disenchantment with mathematics. In my college freshman class, expressions of negative conceptions of mathematics are common. In an essay that asked them to share their thoughts about what mathematics is, one student wrote:

> *"Mathematics. The word itself was enough to instill fear in me. Up until now, I could never fully understand what purpose math had in my life. Whether this was because I was not that good in math, to begin with, or because I had no interest in it in the first place is still unsure. But I was still certain that mathematics would never be of any significance in my life."* ~ Student M, 2020

It is piteous and downright unfair that students seem to be deprived of more interesting, relevant, and realistic mathematics – they deserve more and better. Students do not know what they are missing, however, until you show to them the many fascinating features of mathematics. It is then that they realize how much of the beauty and usefulness of mathematics they have missed. In our freshman math course offering, curated videos and websites about mathematics are part of their course materials. After two weeks spent

on unraveling the many broader concepts and applications of mathematics, students would indeed begin to appreciate mathematics more.

> *"One of the most fascinating characteristics of mathematics to me, is how upon closer inspection, it will appear in nearly every form of occurrence in nature, which can be deciphered through patterns."* ~ Student J, 2020

How can we mathematics educators make up for shortchanging our students in school? How could we share with them the beautiful mathematics that we see around us? How can we enliven their mathematics education experience in schools to encourage a more positive conception of mathematics? Zeigler & Loos (2017) argue for teaching 3 types of mathematics in schools. They identified these as:

Mathematics I: A collection of basic tools, part of everyone's survival kit for modern-day life—this includes everything, but is not much more than, what was covered by Adam Ries' "Rechenbüchlein" ["Little Book on Computing"] first published in 1522, nearly 500 years ago.

Mathematics II: A field of knowledge with a long history, which is a part of our culture and an art, but also a very productive basis (indeed a production factor) for all modern key technologies. This is a "story-telling" subject.

Mathematics III: An introduction to mathematics as a science—an important, highly developed, active, huge research field.

They maintain that the current high school mathematics instruction emphasizes "Mathematics I, with a mechanical instruction on arithmetic, 'how to compute correctly,' and basic problem solving, plus a formal way of teaching Mathematics III as a preparation for possible university studies in mathematics, sciences, or engineering" (p. 74). Mathematics II, which could arguably provide a major component of teaching the beauty of mathematics and offer the needed motivation for studying Mathematics I or III, is largely missing.

3. Culturally relevant mathematics

Attempts to make mathematics more palatable to high school students especially those who have no desire to pursue math-related careers have been made by introducing different foci or themes of curricula, requiring projects that address current social problems or incorporating interdisciplinary activities that link mathematics to another area of study (Chronaki, 2000; Kazima, 2013; Gijsbers, de Putter-Smits, & Pepin, 2020). Some schools include mathematics appreciation activities or inject humor in the instruction (Tap, Mtetwa, & Vere, 2019). Other schools make attempts to bring in the culture of the students by indigenizing learning materials or utilizing arts-based pedagogies (Garcia-Olp, Nelson, & Saiz, 2022; Rigney, Garrett, Curry, & MacGill, 2020).

Perhaps, the biggest attempt that has been quite successful is the Ethnomathematics Research Program that started in Brazil by D'Ambrosio. Although, Ethnomathematics was really intended as a research program, it has expanded its influence on mathematics practitioners and curriculum developers. D'Ambrosio himself said:

> *"Ethnomathematics is fundamentally research in History and Philosophy of mathematics, and this is the reason for calling it the Program Ethnomathematics. But it has obvious pedagogical implications, particularly for curriculum innovation and development, for teaching and teacher education and for policy making."* (D'Ambrosio, 2008, p. 257)

Whether seen as a research program or a framework for curriculum innovation that involves one's culture, Ethnomathematics has sparked numerous curriculum development activities in the Philippines. One recent study by Pacio (2018) aimed to promote awareness and appreciation of the cultural heritage and history of Indigenous Peoples (IP) in their learning of mathematics. To do this, she developed mathematics lessons on patterns for Grade 2 Kankana-ey students of the Cordilleras in Northern Philippines using their own traditional music and musical instruments. The students were divided into two groups, with one group taking the prescribed lessons on patterns using the usual Listen-Absorb-Practice mode of teaching while the other group followed Cordilleran cultural music-integrated lessons. Both groups were also exposed to the same teaching materials, which included picture

cards, flash cards, and art materials. Results of the investigation showed that while both groups learned the lessons as indicated by their assessments, the group that experienced music-integrated lessons benefited more. The students in this group were able to translate the musical beats to mathematical symbols, used the musical instruments to mimic the musical compositions, and were able to compose their own music and translated these to mathematical patterns. The students in the Music group had higher normalized gains in their assessment and exhibited important learning skills in collaboration, in communication; specific skills such as critical thinking, creativity, ability to focus, and the foundational skills in recognizing and generating patterns. Brief interviews with the students revealed they also enjoyed and appreciated the music of their people. The students in the Music group developed a perception that mathematics is a multifaceted and culturally-relevant discipline.

The curriculum innovation developed by Faustino (2021) was her contribution to the lone primary school for the Dumagat people, an IP group located in one of the remote areas in Central Philippines. The Mother-Tongue-Based Multi-Lingual Education (MTB-MLE) program has been in place since the school year 2012-2013, yet not all schools had the pertinent curriculum materials, such as lesson plans even after several years of implementation. Faustino developed lessons on addition and subtraction of fractions using concrete manipulative materials made from the local, everyday objects of the people, such as woven baskets, bamboo sticks, and betel nut leaves. Furthermore, she incorporated the Dumagats' livelihood, their courtship traditions, and recreation into the lesson activities. The woven baskets and bamboo sticks were primarily used to help the 21 students recall the basic concepts of fractions and visualize the actions associated with addition and subtraction of fractions. Faustino investigated the benefits of using indigenous materials in the learning of addition and subtraction of fractions among Grade 4 to 6 Dumagat students, first by looking at the students' success in completing the tasks guided by Bruner's Stages of Representation and second, by studying the students' levels of motivation.

Alangui (2017) reports on curriculum innovations by the Philippine Department of Education (DepEd) that address non-participation and underachievement of the Indigenous Peoples (IPs) in mainstream schools. Recognizing the failure of the Philippine Government to provide an education that is *"non-alienating and sensitive to the needs and aspirations of IPs"* (p. 184), DepEd adopted the National Indigenous Peoples Education Policy Framework through a Department Order issued in 2011. The IP Education Framework covers all subject disciplines. One of two schools that stood out in their efforts to provide a culturally relevant education (CRE) is the PAMANA KA school for Indigenous Mangyan youth in the island of Mindoro. PAMANA KA stands for *Paaralang Mangyan na Angkop sa Kulturang Aalagaan* (literally, a Mangyan school fit to the culture we value). A Grade 5 lesson on the concept of fractions and fraction operations used the context of harvesting honey and rice to emphasize the concept of equal shares when referring to fractions as parts of a whole. The lesson also included discussions of the value of fair share and the negative consequences of greed. A mathematics lesson for first year high school utilized the Mangyan's livelihood of harvesting *cassava* to illustrate algebraic expressions, particularly the concept of variables.

De Villa et al. (2013, as cited in Alangui, 2017) identified five curriculum typologies from among 9 elementary schools, 3 secondary schools and 2 non-formal schools to show the different approaches used in working with Indigenous Knowledge Systems and Practices (IKSP). These are (1) Insertion of cultural elements in specific subjects, (2) Addition of a separate subject to cover IKSP and culture, (3) Integration in the curriculum, (4) Indigenized Curriculum, and (5) IPs Curriculum (p. 191). On the basis of the descriptions of each typology with respect to the focus (IPs competencies vs DepEd's subject competencies) of the lessons and structure of the lessons offered (minimal inclusion of maximal inclusion). The previously cited lessons by Alangui (2017) belong to the Indigenized

Curriculum. These two lessons focused on both sets of competencies and were strongly linked to the Mangyan's community life.

The curriculum initiatives described all have similar features. First, there is a one-to-one pairing between a mathematics lesson or concept and a part of students' culture. Second, these lessons involved only one or two teachers teaching the culturally relevant lesson. It is most likely as well that the lesson was written by just one person. Third, the direction of innovation is often one direction, that is, the lessons are often developed by identifying the mathematical topic first, then is linked to culture. Finally, the lesson contents are all within the prescribed subject curriculum all the time. Extensions might include discussions or activities involving a deeper understanding of the culture and community values rather than extensions of the school subject.

4. Transdisciplinary approaches for culturally relevant mathematics

4.1. Transdisciplinarity

One can think of transdisciplinarity as a framework for developing new forms of knowledge in which there are no firm boundaries between and across disciplines (Robertson & Graven, 2018; Williams et al., 2016). As a framework for curriculum development, transdisciplinarity refers to organizing knowledge units beyond and across disciplines. It is a level of curriculum integration where disciplines move into a common knowledge space outside of their boundaries. Figure 1 shows the continuum of disciplinarity indicating transdisciplinarity as a form past interdisciplinarity.

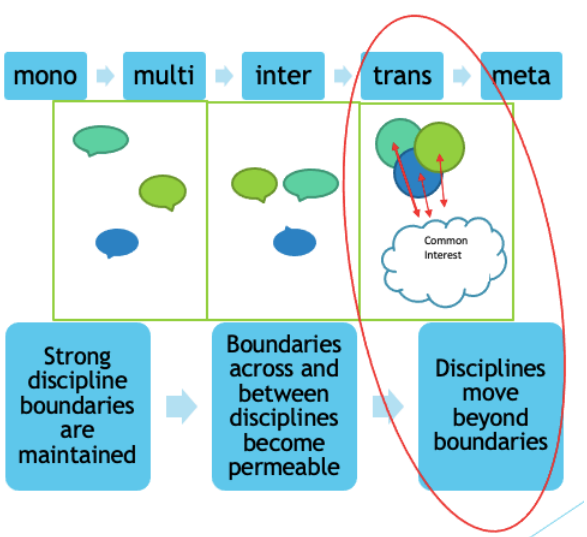

Figure 1. Continuum of Disciplinarity (Robertson & Graven, 2018; Williams et al. 2016))

Hargreaves et al. (1996, cited in Venville et al., 2002, p. 66) contend that curriculum integration involves subsuming previously identified knowledge units or subjects to some relational concepts, blurring the boundaries between the subjects. While educators desire that curricula be integrated, more integration is not necessarily better. Bernstein (1971, as cited in Venville et al., 2002) argues that what is important is the *"relationships between subjects are rigorous, robust, and at a high conceptual level, rather than practical and loosely constructed topics and themes with superficial references to natural connections"* (p. 66).

4.2. Transdisciplinary approaches

According to Drake and Burns (2004, cited in Eronen, Kokko & Sormunen, 2019, p. 266), the multidisciplinary approach to integrating curricula may involve integrating different disciplines in many ways around a common theme, or an identified theme is incorporated into the teaching of different disciplines, or the integration is in the form of service-learning activity in the community. The interdisciplinary approach involves organizing the curriculum around common learning across disciplines. In an interdisciplinary approach the subjects are interconnected beyond a theme or issue and the connections are made explicit to the pupils. A transdisciplinary approach does not begin with the disciplines but begins from a real-life situation or from students' questions and concerns about developing life skills in real-life contexts (Bostan, 2015). In this approach, the students apply interdisciplinary and disciplinary skills in project-based learning, which starts with selecting a topic that students are interested in.

5. A culturally relevant mathematics curriculum: the Mabini Art Movement as context

Following is a real-life situation that has stirred

the hearts of all art-loving Filipinos. A historical extract about one famous part of a once-vibrant city becomes the starting point for a proposed set of lessons for 10th grade students.

5.1. The story

Calle Mabini or Mabini Street, a street parallel to Manila Bay in the district of Ermita, Manila, Philippines, was a popular tourist destination frequented by rich Filipinos and foreign nationals, mostly expatriates. Great artists sold their pieces in the galleries on Mabini Street and art collectors buy regularly from them. Mabini Street lost its lure after the war, which left the city in shambles. To make a living, Filipino artists created and reproduced their artworks in large quantities and sold them cheaply around Luneta Park. Art critics looked down at these works and called them Mabini Art that became synonymous to low-class art. Soon the artists left Mabini Street with their art creations, and galleries closed. Many years down the road the once-charming Manila is now besought with problems caused by overdevelopment. Too many people come to reside there despite too few land areas available for housing. These make Manila less attractive and hardly appealing to both local and foreign visitors (Castro, 2019).

5.2. The problem

Manileños (residents of Manila) who were alive before the war and their families and descendants remember the good old days when their city was a hot tourist destination. The city was alive all day and all night. While some areas have been restored to their former beauty and are conscientiously maintained such as the walled city, Intramuros, many more, including Mabini Street, have yet to be determinedly revived by the city government.

There have been efforts to retrieve the Mabini Art pieces that have left the country and have found their way in galleries located in other cities north or east of Manila. In fact, in the last decade, art exhibits featuring the 'lost' Mabini Art pieces have opened, signaling the revival of the arts created by the great masters of Mabini's art galleries (Zulueta, 2020).

The questions below may thus be relevant to ask by any well-meaning Filipino, especially since Manila is the capital of the Philippines.

1. Can this part of Manila be restored to its former glory? How?

2. Can the Mabini Art Movement become the impetus for this hoped-for restoration? How?

These questions are best answered in a learning space where discipline boundaries are blurred. The historical context is significant, and the problem is meaningful to Filipino students. Although it is obvious that the starting discipline of inquiry if the Arts or Arts Education, other subjects are likewise relevant.

5.3. The syllabus

Getting to know the Mabini Street area (1930s - 1960s)

In this part of the syllabus, students are expected to trace and understand the history of Mabini Street and its contribution to the once-spectacular image of Manila. Understanding the history entails analyzing the social and political conditions back then and the geographic position of Mabini Street.

A detailed study of the 10th grade curriculum (Department of Education, n.d.) shows that four subjects offered in 10th grade – Arts, Araling Panlipunan (Social Studies), Mathematics, and Science are the most suitable to engage in this learning space. Table 1 shows the topics for the subjects Arts, Araling Panlipunan, Mathematics and Science that have been

Table 1: Related topics from each of four subjects in 10th Grade

Arts	Araling Panlipunan (Social Studies)	Mathematics	Science
Types of visual art	History of Manila	Street map	Tectonic plates in Manila
Principles of Art	Culture and Tourism	Landmarks in the area	Proximity of Manila Bay

identified to be directly related to and useful in understanding the problem. These topics are all to be covered in Quarter 2, simultaneously, within each subject.

The Mabini Art Project: 100 Paintings

In this part of the syllabus, students investigate one exhibit by Freddie and Isabel Aquilizan who transformed a large-scale oil on canvas piece by Antonio Calma, a Mabini Street artist. They cut it up into 100 various-sized rectangles and had each of these framed and displayed. Sharjah Art Foundation (n.d.) and Manila Art Blogger (n.d.) give more details on the exhibit. Figure 2 shows a photo of its display at the Ateneo Art Gallery. The ceiling-to-floor wall display becomes the object of a mathematics activity.

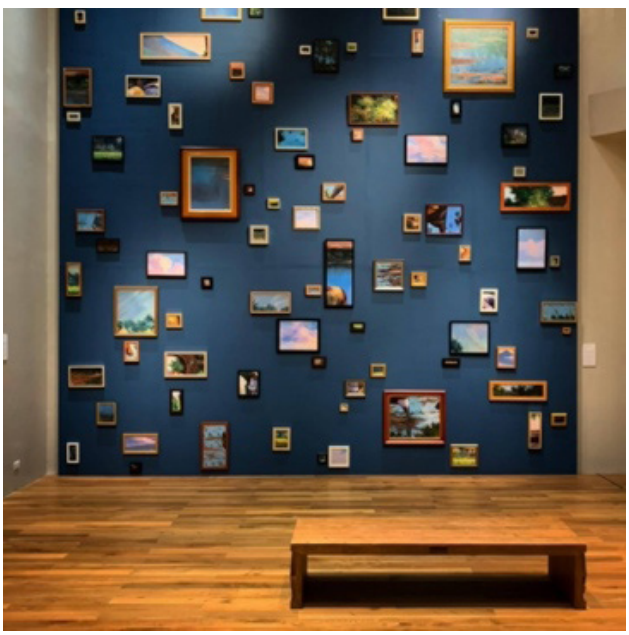

Figure 2. The Mabini Art Project: 100 Paintings at the Ateneo Art Gallery

A Mathematics Activity

Goal 1: Find interesting patterns in The Mabini Art Project: 100 Paintings by studying

a. the size and make of the frames

b. orientation of the pieces of the canvas

c. locations of each frame on the wall.

d. distances between frames

To accomplish Goal 1, students will be expected to 1) find ways to gather the information needed possibly through interviews with the artists, and 2) read up on historical documents, art blogs, and magazine articles. The mathematics concepts at work are the 1) Cartesian plane 2) mapping 3) distance between points, and 4) other related concepts in the beginning lessons in analytic geometry. The recommended time frame to accomplish the learning outcomes is two weeks with three to four contact hours with the students.

Goal 2: Decide on another arrangement of the 100 frames. What was your basis for the rearrangement?

To accomplish Goal 2, students are expected to discuss their approaches with their classmates using various points of views. Discussions are expected to be enriched with mathematical concepts, which should form the bases for other arrangements. Students will compare their works, hopefully, using mathematical computations to strengthen their arguments for patterns they choose to use. A time frame of one week would be enough.

Goal 3: Which of the various rearrangements are visually pleasing? What criteria did you use?

To accomplish Goal 3, students talk about their personal preferences for visual arts and try to define the concept of beauty and what is visually pleasing. This part of the activity leads students toward lessons in art. Further, discussions could be enhanced by combining mathematics principles and notions of beauty in visual arts. A time frame of two hours would be sufficient.

Segueing to the Arts

Goal 1: Study the Mabini Art Project according to the following principles

- Rhythm, Movement
- Balance
- Emphasis
- Harmony, Unity, and Variety
- Proportion
- Which of these make the wall visually pleasing to you?

In this part of the syllabus and to accomplish the above Goal 1, students are expected to learn the different types of visual arts and the principles of art used in different genres.

5.4. Some notes

The sample partial syllabus presented focuses on a context that students of different Filipino cultures and traditions could relate to. These include students living in both city and rural settings, students belonging to indigenous cultures, and students who have interests in any of the arts and culture, mathematics, science, and social science, as the art creations from the great masters of the Mabini Art Movement include indigenous arts, landscapes depicting rural life, and various genres that art afficionados and non-afficionados are exposed to in their daily lives.

Further, in characterizing the transdisciplinary approach to developing a culturally relevant mathematics curriculum, one could see its contrasting features from the approaches used by Pacio (2018), Faustino (2021), and Alangui (2017). The sample partial syllabus (1) illustrates a many-to-many correspondences between the school subjects and aspects of the culture they connect to, (2) starts with a context, an event, a situation within the students' milieu, (3) shows opportunities for teachers and students to create knowledge, and (4) contains activities or lessons that could predictably go in various directions.

6. Next steps

There is no shortage of efforts by mathematics educators in designing culturally relevant mathematics lessons. Whether these are successfully done or not is a different matter. For a country such as the Philippines, Western-oriented mathematics is no longer enough to provide the kind of mathematics education that our citizens need because of problems and situations that are uniquely Filipino. Hence, it is imperative that mathematics educators continuously find ways to integrate students' culture and contexts in school mathematics.

To follow up on this curriculum development effort, the next two steps will be pursued. First, the syllabus needs to be expanded to make science and social science more explicit. Second, teachers of these subjects must come together to validate and enrich the syllabus initially designed by the author who is a mathematics educator. This step is perhaps the most tedious and time consuming as there will surely be many arguments and proposals on the table to make the process better.

Acknowledgments

The author thanks Jake Hofileña for the photo of *The Mabini Art Project: 100 Paintings* at the Ateneo Art Gallery.

References

Alangui W.V. (2017). Ethnomathematics and culturally relevant mathematics education in the Philippines. In Rosa, M., Shirley, L., Gavarrete, M., & Alangui W. (eds) *Ethnomathematics and its diverse approaches for mathematics education. ICME-13 monographs*. Springer, Cham. https://doi.org/10.1007/978-3-319-59220-6_8.

Bernstein, B. (1971). On classification and framing of educational knowledge. In M. F. D. Young (Ed.), *Knowledge and control: New directions for the sociology of education*. London: The Open University.

Bostan, C. G. (2015). Inter- and transdisciplinary issues present in the school curriculum. *Procedia - Social and Behavioral Sciences*, *180*(5), 489–496.

Brown, M., Brown, P., & Bibby, T. (2008). "I would rather die": Reasons given by 16-year-olds for not continuing their study of mathematics. *Research in Mathematics Education, 10*(1), 3-18. DOI: 10.1080/14794800801915814

Castro, A. (2019, February 20). *The forgotten art of Mabini Street: From tourist souvenirs to mainstream masterpieces*. Esquire. https://www.esquiremag.ph/culture/books-and-art/mabini-street-art-a2289-20190220-lfrm3

Chronaki, A. (2000). Teaching maths through theme-based resources: Pedagogic style, `theme' and `maths' in lessons. *Educational Studies in Mathematics, 42*, 141–163. https://doi.org/10.1023/A:1004124328308

D'Ambrosio, U. (2000). Stakes in mathematics education for the societies of today and tomorrow. In D. Coray, F. Furinghetti, H. Gispert, B. R. Hodgson & G. Schubring (Eds.), *One hundred years of L'Enseignement Mathématique moments of mathematics education in the twentieth century proceedings of the EM–ICMI Symposium*. Geneva, 20–22 October 2000, 301-316.

D'Ambrosio, U. (2008). How mathematics education can help in shaping a better world. *ICME-11 Proceedings*, Monterrey, 6-13 July 2008, 248-263. https://www.mathunion.org/fileadmin/ICMI/files/About_ICMI/Publications_about_ICMI/ICME_11/D_Ambrosio.pdf

De Villa, M. T., Alangui, W. V., Jaro-Amor, I., & Martin, F. (2013). *Developing an IP curriculum framework. Philippines: Report submitted to the IP Education*

Office, Department of Education and Culture, Republic of the Philippines.

Department of Education. (n.d.). K to 12 basic education curriculum. Republic of the Philippines Department of Education. https://www.deped.gov.ph/k-to-12/about/k-to-12-basic-education-curriculum/

Drake, S. & Burns, R. (2004). *Meeting standards through integrated curriculum*. Alexandria, VA: Association for Supervision & Curriculum Development.

Eronen, L., Kokko, S., & Sormunen, K. (2019). Escaping the subject- based class: A Finnish case study of developing transversal competencies in a transdisciplinary course. *The Curriculum Journal*, *30*(3), 264-278, DOI: 10.1080/09585176.2019.1568271.

Faustino, H. L. P. (2021). Learning addition and subtraction of fractions through the use of indigenous materials: The case of Dumagat elementary students. [Unpublished master's thesis]. Ateneo de Manila University.

Garcia-Olp, M., Nelson, C., & Saiz, L. (2022) Decolonizing mathematics curriculum and pedagogy: Indigenous knowledge has always been mathematics education. *Educational Studies*, *58*(1), 1-16, DOI: 10.1080/00131946.2021.2010079

Gijsbers, D., de Putter-Smits, L., & Pepin, B. (2020) Changing students' beliefs about the relevance of mathematics in an advanced secondary mathematics class, *International Journal of Mathematical Education in Science and Technology*, *51*(1), 87-102, DOI: 10.1080/0020739X.2019.1682698

Hargreaves, A., Earl, L. & Ryan, J. (1996). *Schooling for change: Reinventing education for early adolescents*. London: Falmer.

Kazima, M. (2013) Students' preferences for contexts and their relevance to school mathematics in Malawi. *African Journal of Research in Mathematics, Science and Technology Education*, *17*(3), 244-254, DOI: 10.1080/10288457.2013.848537

Manila Art Blogger. (n.d.). *"Mabini art project: 100 paintings" now belongs to the Ateneo Art Gallery*. https://manilaartblogger.wordpress.com/2011/03/22/mabini-art-project-100-paintings-now-belongs-to-the-ateneo-art-gallery/

MATHTED & SEI. (2010). *Mathematics framework for Philippine basic education*. Manila: SEI & MATHTED.

Murray, S. (2011) Declining participation in post-compulsory secondary school mathematics: Students' views of and solutions to the problem. *Research in Mathematics Education*, *13*(3), 269-285, DOI: 10.1080/14794802.2011.624731

Pacio, M. T. (2018). Learning mathematics by using Cordilleran cultural music in the study of patterns: A case of ethnomathematics in primary school. [Unpublished master's thesis]. Ateneo de Manila University.

Park, K. & Brombacher, A. (n.d.). *The role of mathematics in the overall curriculum*. ICMI. https://www.mathunion.org/icmi/role-mathematics-overall-curriculum

Pradel, D. A. (2019). Crests and troughs: the use of trigonometric modeling towards a critical and realistic mathematics education. [Unpublished master's thesis]. Ateneo de Manila University.

Pradel, D. A. & Vistro-Yu, C. (2021). Crests and troughs: the use of trigonometric modeling towards a critical and realistic mathematics education. A paper presented at the 14th International Congress on Mathematical Education (ICME-14), 11-18 July 2021, Shanghai, China.

Rigney, L., Garrett, R., Curry, M., & MacGill, B. (2020). Culturally responsive pedagogy and mathematics through creative and body-based learning: Urban Aboriginal schooling. *Education and Urban Society*, *52*(8), 1159–1180. https://doi.org.oca.rizal.library.remotexs.co/10.1177/0013124519896861

Robertson, S-A. & Graven, M. (2018). Using a transdisciplinary framework to examine mathematics classroom talk taking place in and through a second language. *ZDM*, *50*, 1013–1027. https://doi.org/10.1007/s11858-018-0952-2

Sharjah Art Foundation. (n.d.). *Mabini art project: 100 paintings*. http://sharjahart.org/sharjah-art-foundation/projects/mabini-art-project-100-paintings1

Tap, W. D., Mtetwa, D. K., & Vere, J. C. (2019). Using humour for generating and maintaining Interest in mathematics among secondary school students in South Sudan re-settled communities. *African Journal of Research in Mathematics, Science and Technology Education*, *23*(2), 244-253. DOI: 10.1080/18117295.2019.1656871

Venville, G. J., Wallace, J., Rennie, L. J. & Malone, J. A. (2002). Curriculum integration: Eroding the high ground of science as a school subject? *Studies in Science Education*, *37*(1), 43-83. DOI: 10.1080/03057260208560177.

Williams, J., Roth, W-M., Swanson, D., Doig, B., Groves, S., Omuvwie, M., Borromeo Ferri, R., Mousoulides, N. (2016). *Interdisciplinary mathematics education, a state of the art*. Switzerland: Springer Open.

Ziegler, G. M. & Loos, A. (2017). "What is Mathematics?" and why we should ask, where one should experience and learn that, and how to teach it. In G. Kaiser G. (Ed.), *Proceedings of the 13th International Congress on Mathematical Education. ICME-13 Monographs*. Springer, Cham.

Zulueta, L. B. (2020, February 17). Mabini art makes a comeback. Philippine Daily Inquirer. https://lifestyle.inquirer.net/357512/mabini-art-makes-a-comeback/