Analyzing Principles of Integration

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This paper will describe a possible topic and project for an integrated curriculum unit that could be implemented in an international secondary school setting following an International Baccalaureate Middle Years Programme (IB MYP) curriculum framework. A rationale for the choice of disciplines, topic and project, supported by literature and taking into account the local context of the setting, will be presented. Possible examples of how the five principles of integration might be applied in a unit-specific context will also be examined.

Deciding on the Disciplines

The two disciplines to be integrated are mathematics and design. The initial rationale for choosing these two in particular came from Kubat and Guray's 2018 article "To STEM or not to STEM? That is not the question", in which they discuss how design-based tasks and projects are a natural way to integrate STEM disciplines. We can think of design as a natural bridge between science and mathematics – it literally puts the "T" and "E" in between science and mathematics in the acronym STEM. Considering the local and particular context, the author currently teaches mathematics and has a mechanical engineering background and shares an office with several design teachers. While the mathematics department at the author's school participates in several interdisciplinary units ("IDUs") each year, none of these currently involve design.

Another reason for choosing an integrated mathematics and design unit is its strong potential for including each of the six A's of integrated curriculum, as outlined by Clayton et al. (2010). Authenticity and applied learning are an intrinsic part of the design cycle (Lohmeyer, n.d.), and there is potential to arrange active exploration beyond the classroom and adult connections with community experts through our relationship with RMIT University, Ho Chi Minh City campus. Academic and technical rigour (key learning standards) and assessment practices will be discussed later in the paper. Yet another connection with the literature can be seen in Fogarty's 1992 model of the continuum of integrated curriculum. Initially, the unit described in this paper would follow the shared model, but there is potential to involve other departments and move towards a webbed (thematic) or integrated model in future iterations.

To identify potential topics for the unit and narrow the focus to a subset of achievable learning outcomes for each discipline, recent updates to the IB mathematics syllabi were considered. In their 2017 evaluation of the IB MYP Mathematics Skills Framework, Hoon et al. wrote that including algorithms in the list of algebra topics was a sufficient introduction to discrete mathematics at the middle school level, and that the inclusion of network and path problems or a separate discrete mathematics branch was not necessary. However, starting from the 2021-2022 school year, network pathways have been added to the new version of the framework (MYP Maths, 2020). Moreover, the new IB Diploma Programme (DP; the final two years of high school) mathematics course "Applications and Interpretations", introduced in 2019, also contains significant discrete mathematics content (International Baccalaureate Organization, 2019). Taken together, these suggest a shift in IB mathematics curriculum towards discrete mathematics, the branch of mathematics that is most closely associated with computer science. The MYP Design curriculum at International School Ho Chi Minh City (ISHCMC) includes food design, product design and digital design, the latter being responsible for the teaching of programming skills (International School Ho Chi Minh City, 2020). Thus, the interdisciplinary topic of algorithms was selected as the focus of the unit.

With regards to learning environment factors particular to the setting, ISHCMC secondary leadership has been supportive of providing IDU planning time over the past three years, and all students experience IDUs in Grades 6-8. This becomes logistically more difficult in Grades 9 and 10 due to the streaming of mathematics cohorts into different levels, the provision of elective design units and the ensuing timetabling complexities. This structure results in not all students studying digital design in Grades 9 and 10, and those that do choose digital design do not study it continuously throughout a given academic year, which constrains the mathematics units that it could potentially be combined with. By including the mathematics content of the integrated unit in all streams and aligning the relevant mathematics unit to coincide with the appropriate digital design elective unit, it is at least possible to ensure that all students who choose to study digital design could participate in the unit. Shared teaching timeslots would likely be impossible to schedule; however, it may be possible to arrange for mathematics teachers to visit the design classes on a roster basis, and it is likely that shared planning time could be arranged. Regarding resources, it is likely that all lessons could be delivered using existing department materials and open source software platforms such as Geogebra (a browser-based graphing and geometry tool commonly used in secondary mathematics classrooms) and any suitable online Python coding platform.

Considering current best practices in the teaching of the disciplines, the constructionism theory of learning can be successfully applied to both mathematics and design. Csizmadia et al. (2019) found that found that activities promoting the development of algorithmic thinking are “particularly suited to constructionism” (p. 61), and Geraniou and Mavrikis (2015) reported success in using digital manipulatives to improve outcomes in a pre-algebra unit. It should not be surprising that a constructionist approach is particularly applicable to design projects, as it is effectively asserting that students learn by making things. Finally, one can point to the high school progression descriptors of the Next Generation Science Standards Science and Engineering Practice “Using Mathematics and Computational Thinking” (National Science

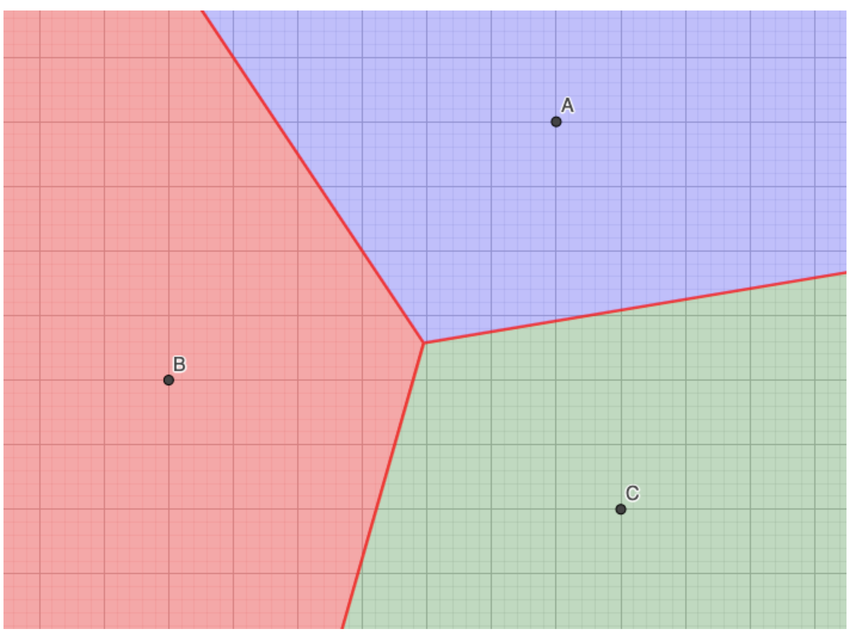
Teaching Association, 2014) as further validation of the choice of unit topic, and indeed, the IB's shift towards discrete mathematics.

Deciding on the Topic and Problem/Issue

The inspiration for the choice of specific topic and problem came from a 2020 article by Tran about using Python to compute Voronoi diagrams. Essentially, a Voronoi diagram divides a coordinate grid (such as a map) into regions of closest proximity to particular points. In this case, the points of interest are hospitals, and the aim of the app is to overlay a Voronoi diagram on a map of a city or region in order to assist the user in choosing the nearest one. An example and brief explanation of Voronoi diagrams is given in Figure 1 below.

Figure 1

Example Voronoi Diagram



Note. All points in the respective shaded regions are closer to the points they contain than the other points. The red lines represent locations of equal distance between each pair of points and are constructed by drawing a line perpendicular to and through the midpoint of an imaginary line connecting each pair of points.

The application of Voronoi diagrams described by Tran (2020) could easily be adapted to the local context by tasking students with creating a Voronoi diagram app that would allow a user to find the nearest “X” in Ho Chi Minh City, where “X” could be any useful location of the student’s choosing, as long as it meets certain criteria such as being one that has multiple outlets in the city and one that people might want to visit regularly. As an example, there is a convenience store chain in Ho Chi Minh City that offers free battery swaps for electric bike users and knowing where the nearest store is located would be useful information for electric bike users low on battery. As part of the design cycle, students would be expected to justify their choice of location based on market research and explain to potential users how the features of their app benefit the user more than a simple Google Maps search would.

The mathematics required for Voronoi diagrams can be flexibly integrated into any Grade 9 or 10 algebra or geometry unit, and algorithm development and coding can form part of any digital design unit. An interdisciplinary line of inquiry can be drawn from Tran’s statement “It would be difficult and computationally expensive to compute the Voronoi diagram for every point at once.” (2020, Implementation with Iterative Algorithm section, para. 3). This can lead to investigations of how different algorithms designed to achieve the same result (a digital design topic) can cause the number of computations required to increase in different ways as the complexity of the problem (in this case, the number of points on the map) increases. For example, one particular algorithm might cause the number of computations to increase in proportion the number of points squared (n^2), while another might cause them to increase logarithmically (in proportion to log (n)). This naturally leads to the study of patterns and functions in mathematics. The results of these investigations could then be linked to the design problem of the trade-offs involved in increasing computational power.

Incorporating Principles of Integration

Now that the disciplines to be integrated, topic, and problem/issue have been chosen, it is possible to start to consider how each of the five principles of integration might look in a unit-specific context. Some possible examples are shown in Figure 2 below.

Figure 2

Graphic Organizer Explaining the Five Principles of Integration in the Unit Context

Incorporating the 5 principles of integration

Principle	Definition	Unit-specific example
Connections to experience	Links between current learning, prior knowledge and life experience	Prior knowledge of scale and distance and algebra; life experience of using maps and apps
Connections to discipline	Applying and synthesizing perspectives from multiple disciplines to a particular topic	Computational efficiency is investigated through the lenses of both mathematics and design
Transfer	Using generally applicable skills and knowledge in different situations across disciplines	Both Geogebra and Python involve giving commands to a computer using a particular syntax
Integrated communication	Using multiple forms of communication in a synergistic way in the final product	User instructions, app promotional videos and presentations for clients are all possible forms
Reflection and self-assessment	Demonstrating a meta-awareness of the learning process, its relevance and how to improve it	Students could keep a project journal, and write a lessons learned file at the project conclusion

Conclusion

Design projects offer a natural lens through which to implement an integrated curriculum unit. The six A's of integrated curriculum are easily implemented within such projects and they offer students multiple opportunities to develop 21st century skills related to the use of information technology and working in project teams. With due consideration of local context, units such as the one described in this paper could be easily adapted for most secondary school settings, thus developing key computational thinking skills our future workforce.

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