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Cross-curriculum Integration of Mathematics in Secondary Schools

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Abstract

It is a known fact that the quality of education that teachers provide to students is highly dependent upon what teachers do in the classroom. Thus in preparing the students of today to become successful, innovative, resilient individuals of tomorrow, it is imperative for mathematics teachers to ensure their teaching is effective and broad spectrum. Integration of mathematics across other curriculum is a vital ingredient to ensure a well-rounded young adult of the future. Through interdisciplinary approaches a student will experience a view of knowledge and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience.

This paper will explore the possibilities of integrating mathematics within other disciplines and consider how another subject can support and enhance student's learning in mathematics. Considerations and recommendations of the implementation of integration process will be considered.

Keywords: Mathematics, cross-curriculum, inter-disciplines, STEM, Integration

Introduction

It is first necessary to clarify the distinction between disciplinary courses and cross-disciplinary courses. Disciplinary courses usually deal with a specific field of knowledge, delving relatively deep into details and micro aspects. It is more focused on a specific field of knowledge, rather than with integrating with other disciplines. Cross-disciplinary courses are connections, interrelations and interactions between different fields of knowledge (Frykholm & Glasson, 2005). These courses are more general in character and they can be called macro-courses.

In an era characterised by rapid accumulation of new information, dominated by science, technology and mathematics, cross-disciplinary theories can help teachers and students control, manage and understand large amount of information better and hence it is essential that mathematics be taught as a subject that lends itself to other subject areas and teachers need to be equipped with the necessary skills to ensure this. A useful way to apply connected curriculum is to use mathematics as the thread that links Science, Technology, and other curriculum together.

Research indicates that using interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners (Frykholm & Glasson, 2005). Interdisciplinary teaching is dependent on:

- the way students best acquire knowledge
- having a positive impact on students during their developmental stage
- influencing the teaching of the subjects
- the cooperative involvement of both teachers and students planning and learning together so that the end product is attained.

The concept of ‘separate subject’ or ‘layered cake’ approach of education should be eliminated. Students often cannot solve problems because they don’t understand the concepts in which the problems are embedded. Students should see their learning as a continuum throughout their subject and be able to apply their mathematical knowledge confidently to other discipline areas.

However, there are challenges associated with its implementation. The greatest challenge being a test driven curriculum where students and teachers are evaluated on student performance based standardised test scores.

It is not that schools should avoid dealing with specific disciplines; rather, they need to create learning experiences that intermittently demonstrate the relationship of the disciplines, hence enhancing their relevancy. There is a need to actively show students how different subject areas influence their lives, and it is critical that students see the strength of each discipline perspective in a connected way. Students should be aware of how the branches of mathematics interconnect with each other and the whole school curriculum. More teachers are now seeing the virtues of cross-curricular lessons and there are so many

historical events and technological and scientific breakthroughs that can be linked to mathematics, which gives more context and relevance to the subject.

If done properly, integration of mathematics with other subjects could bring together overlapping concepts and principles in a meaningful way and enrich the learning context which could result in meaningful learning experiences.

Considerations and Recommendations

Learning is an active mental process in which connections are made between experience, prior knowledge and new ideas, to develop and refine student's knowledge and understanding of a subject or topic.

What would be the most appropriate manner to integrate the lessons? The following need to be considered:

- Base integration on how students experience, organise and think about Mathematics, and other disciplines, for example, Science or Design and Technology.
- Students often look at patterns and link them to make sense of the world, hence teachers need to look at patterns in this manner too
- Teachers need to collect and use data in problem based integrated activities that enhances process skills
- Take into cognisance the students' confidence and interest in the different subject areas: they might have a passion for Science but not Geography
- Instructional strategies should be used to help bridge the gap between students' classroom experiences and real life experiences
- Be aware of not losing subject identity in cross-curricular projects due to planning a topic whose focus has been on the product rather than the process of learning and the unique contribution of each subject to that learning

The concept of integration requires the teacher to consider whether they want to teach Mathematics entirely as a part of the other discipline, for example Science, or teach Science entirely as part of Mathematics or use Mathematics as a language tool for teaching other disciplines. It is important that the teacher feels comfortable and confident teaching the two disciplines. Such issues need to be addressed before the implementation of the integration process. The teacher should have access to extra professional development, if necessary. The process will require the time of two or more teachers for common planning and curriculum development where consensus building and professional collaboration will occur.

Some of the essential criteria will be:

- Lessons or units of work should complement and support the learning skills in at least one of the disciplines
- The lesson/unit should encourage and enhance the students' interest to integrate and use the knowledge and skills from different areas of competence

Some of the techniques to be used could involve hands on activities to make the lessons concrete, encourage cooperative group work, use discussion and enquiry based techniques, instil valid and meaningful questioning and inference strategies, use justification of thinking, use problem solving approaches to instruction, use assessment as part of instruction and most important of all endorse the role of the teacher to that as a facilitator of learning.

Problem solving is often an area where Mathematics overlaps with many other disciplines and can be integrated, hence problem based learning might be a successful instructional strategy for integration. There is no room for rote learning in these processes.

When assessments and assignments are administered, detail rubrics are necessary to take into account the processes involved rather than merely stating the answers. Assessments should be aligned with the curriculum's goals, the relevant content from disciplines as well as instructional processes and hands on activities including manipulatives. Hence alternate assessment styles are imperative. Assessments should also take the form of observations, interviews, performance tasks, student self- assessment, portfolios, enquiry based questions and standardised tests (Singh, 2014). Assessments should be practise based on the type of information sought and how the information will be used. This has to be in keeping with the maturity levels of the students. Hence students should be given multiple opportunities to demonstrate their knowledge and understanding of the disciplines being tested.

Discussion

There are various models that can be implemented. Five models are discussed.

Discipline-Based Content

The discipline-based content design option focuses on a strict interpretation of the disciplines with separate subjects in separate time blocks during the school day. There may be some variations of block scheduling and the way the week or cycle is programmed. Knowledge is presented in separate subjects without a deliberate attempt to show the relationships among them. This is the most common format used and students, parents and teachers are used to it. It is efficient because courses of study and national outcomes and objectives are available in each discipline through all grade levels, and

curriculums, tests, and supplementary materials exist for each specific subject. Focusing on each discipline provides students with specialized skills and concepts in a subject area. Secondary teachers are trained in a special discipline area, thus being able to reinforce the theory of the discipline as a specialist. The problem with this approach is its fragmenting effect on the student's school day. Students do not learn how the perspective of one discipline relates to another. In real life situations, problems are not discipline specific in regimented time blocks.

Parallel Discipline Designs

In this model, teachers re-sequence the order of the topics to correspond and run parallel with another discipline. For example if a mathematics teacher is teaching the topic on measurement to a year 9 class, then the design and technology teacher could start the project on designing a jewel box. The concepts and understanding and application of measurement will be covered in both discipline areas. The aim is a simultaneous effect as students relate the studies in one subject with another. Teachers working in a parallel fashion are not deliberately connecting curriculum across fields of knowledge; they are simply re-sequencing their existing curriculum in the hope that students will find the implicit linkages. This method is easily applied to mathematics as there is a fair amount of flexibility in the order in which topics can be taught unlike some other disciplines.

The Shared Model

Overlapping concepts of the 2 disciplines is identified and applied in this model. Teachers then share the planning and preparation of the topics. Sometimes it is necessary for one teacher to teach both disciplines. Discussion by the teachers would be around what common concepts the units share and similarities in the skills being taught. The essence of this method is that the designers attempt to use a full selection of discipline-based viewpoints. The units are of specific duration: a few days, a few weeks, or a semester. The advantage is teachers can plan their interdisciplinary work around themes and issues that emerge from their ongoing curriculum. The downside of this method is one of timing, time for planning, and determination and enthusiasm on the part of the planners.

The Weaving Model

This model weaves thinking skills, social skills, study skills, technology and multiple intelligences approach to learning throughout the disciplines (Jacobs, 1989). Interdepartmental teams can target a set of thinking skills to permeate into existing content priorities. Hence thinking and social skills are woven into the content. Some questions that teachers could ask are: "what thinking skill did you find most helpful?", "how did you think about that?", "how well did your group work today?" These processing questions contrast sharply with the cognitive questions such as "what answer did you get?"

The Engrossed model

Integration takes place *within* learners, with very little or no intervention from outside. These learners integrate all data by funnelling them through an area of interest. For example a year 7 student may have a curiosity in butterflies. The students' artwork will be modelled on the symmetrical design (learned from mathematics) of these creatures. The student could be a collector of butterflies and hence will be counting and mounting them in some sequential order, again from the topic patterns in Mathematics. He/she could even write about them in English essays. Hence his/her interest in insect biology will be absorbing much of his/her time. As a result, the student will be using many varying knowledge skills from the various disciplines studied. Engrossed learners are constantly making connections to their subjects.

An obvious challenge when planning cross-curricular work is maintaining an appropriate balance between the subjects which contribute to the study. So having a clear rationale for including subjects in the theme or topic helps to maintain the rigour of the study. It could also prove to be costly as funds are needed to support best practices and long-term planning.

Advantages of Cross Curriculum Teaching

Cross-curricular teaching and learning has strong links with the constructivist view of learning, as students work collaboratively and learn from their own direct experience (Kerry, 2011). Hayes (2010), who is a strong advocate for cross-curricular work, argues that individual subject disciplines only give a partial insight into a particular topic or problem, and that to enable them to fully understand the problem; students need to be encouraged to draw together insights from different subjects. Consider, for example, teaching children about measurement in Mathematics. In which other subjects will students use this knowledge and develop their ability to make accurate measurements? How does making accurate measurements when cooking or when making an artefact in Design and Technology help develop student's competence with the concept of measurement in Mathematics? To be effective, the links between subjects need to be made explicit, because it should not be assumed that skills and knowledge learned in one context will be transferred to a different context (Hayes, 2010). This is not a simple task, as it requires teachers to have good knowledge of a range of different subjects, which includes being sensitive to the culture or values of a subject as well as the concepts, knowledge and skills inherent in that subject. Recent literature about cross-curricular work confirms that it improves students' motivation and engagement, as learning is placed in a context that is both interesting and relevant to the learner (Barnes & Shirley, 2007).

Another reason that cross-curricular work is motivating is that it allows for more independent, learner-led exploration of the topic (Muijs & Reynolds, 2011). This appeal to the emotional aspects of learning resonates with a growing understanding of how emotions affect learning. Students are more prepared to make the effort to learn something that is thought to be 'difficult'

when they are interested in the topic, and it is more difficult to learn when they are not interested or do not see the point of learning something. Teachers feel elated when the students in their class are engaged and show interest and enthusiasm for a particular lesson or topic.

Perhaps one reason that cross-curricular work improves motivation and engagement is the breadth of study. For some students it will be the Science aspect that interests them, whereas for others it might be another subject such as Mathematics, History or Art. We as teachers have given the students an opportunity to have this broad spectrum exposure to various subjects by the process of interdisciplinary integration.

Conclusion

Integrated curriculum attempts should not be seen as an interesting diversion but as a more effective means of presenting the curriculum. It is obvious that we cannot train people in specialisations and expect them to cope with the multifaceted nature of their work. Students need to be given the exposure and opportunities so that they may draw from the range of areas to better serve their specific interests. The renewed trend in schools toward interdisciplinary teaching will help better integrate strategies from their studies into the larger world. One must be aware of avoiding the "Potpourri Problem" where many units become a sampling of knowledge from each discipline (Jacobs, 1989). Curriculum developers themselves must design carefully considered strategy featuring:

- A scope and sequence
- A cognitive taxonomy to encourage thinking skills
- Behavioural indicators of attitudinal change
- A thorough and meaningful evaluation scheme so that solid and lasting designs will emerge

The teacher should therefore be empowered to work as a designer, to shape and to edit the curriculum according to the students' needs.

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