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A new model for the integration of science and mathematics: The balance model

S. Ahmet Kiray*

Selcuk University, Ahmet Kelesoglu Faculty of Education, Konya, Turkey

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Abstract

The aim of this study is to develop an integrated scientific and mathematical model that is suited to the background of Turkish teachers. The dimensions of the model are given and compared to the models which have been previously developed and the findings of earlier studies on the topic. The model is called the balance, reflecting the significance of balance in the process of integration. The balance model includes five dimensions: content, skills, the teaching-learning process, affective characteristics, measurement and assessment. The goal of the balance model is to keep the content/standards the same as their original values.

Keywords: Integrated science and mathematics; Integration of science and mathematics; Integrated curriculum

1. Introduction

As a result of the recent increase in knowledge, it is necessary to categorise knowledge that was previously classified as natural philosophy under different headings [1, 2]. At the beginning of the last century, attempts at developing new disciplines and determining their boundaries became popular, partly as a result of the positivist approach. The positivist approach regards the world as the sum of small and independent parts, and adopts the view that a detailed examination of these parts would produce a better understanding of the whole [3, 4]. This approach provided the philosophical background for discipline-based educational programmes. However, the need to connect the separate disciplines became apparent as the parts were further differentiated. Therefore, pragmatic assumptions replaced positivist assumptions. Pragmatic philosophers point out that knowledge is a single entity in daily life and that knowledge cannot be contained in a single discipline. Therefore, instead of reaching the whole through its parts, the whole should be used in order to reach the parts. This view, which contradicts the discipline-based approach to education, has resulted in the integrated curriculum approach in the field of education.

*Corresponding author. Tel.: +90-532-592-0219; fax: +90-.
E-mail address: ahmetkiray@gmail.com (S. A. Kiray).

1. 1. Integrated curricula

The concept of integration is not new in terms of educational programs [5]. The integrated curriculum approach appeared with the project approach in the USA during the 1920s. It was called the core curriculum during the 1930s and the problem-centred core curricula during the 1940 and 1950s. During the 1980 and 1990s, it was termed the multidisciplinary, interdisciplinary and transdisciplinary curricula [6]. Dewey's report influenced teacher training in the 1930s and the elementary curricula in 1948 in Turkey. The elementary curricula of 1948 consisted of an approach whereby all courses were integrated under the headings of life sciences, natural sciences and family knowledge. This curriculum, which focussed mainly on social issues in a period in which the world had become highly polarised, was criticised because of its weakness in terms of scientific content. These criticisms led to a further division of courses in 1968, when science and mathematics were first included in the middle school curricula as separate courses. The science course in this curriculum was a combination of physics, chemistry and natural sciences [7]. It was called complete science in 1976, and its science content was separated from its mathematics content, as it is in the current science and technology course. In the same curriculum, the mathematics course was called modern mathematics, and its connection to other courses was completely eliminated. In other words, modern mathematics was purely mathematics, while complete science was purely science [7]. The same approach is also dominant in the current educational approach and its implementation in Turkey. In the middle school curricula, the connections between the science course and the mathematics course are minimal, if there are any [8]. Although attempts at an integrated curriculum were first made at least a century ago, many countries (including Turkey) have not paid any attention to these attempts. Instead, a strict, discipline-based approach to the curriculum is common in these countries.

1. 2. The need to connect science and mathematics

The need to connect the disciplines which are included in school curricula has been intensely discussed and emphasised in recent studies [9-19]. It is certain that this need exists for all disciplines. However, this is particularly true of certain topics in the courses of science and mathematics. The disciplines of mathematics and science are much more suitable for integration because of their fields of application and their mutual scientific approach towards problem-solving [20]. Science and mathematics are two closely related systems of knowledge; they are both related to the physical world, and science provides concrete samples, while mathematics provides abstract samples [21, 22]. The belief, held by mathematicians, that mathematics can be learned more meaningfully when its techniques are employed for the resolution of problems which are outside of the field of mathematics [14, 17, 23] can be reinforced and realised through the adaptation of scientific content and processes in the problems used in mathematical studies [14-16, 19]. On the other hand, some studies have concluded that the transfer of mathematical content or skills into a science course can positively affect the students' understanding [2, 24-27]. Moreover, many researchers have stated that using mathematical quantitative knowledge when explaining scientific concepts leads to a deeper understanding on the part of the students [22, 23, 28-31]

1. 3. Previous views on the integration of science and mathematics

The recognition of the interrelationship between science and mathematics has naturally increased the number of the studies on this topic. However, as observed in other fields of study, different terms and concepts are used to refer to the same (or at least similar) facts or assumptions. This leads to contradictions regarding the understanding of the connections between the two [13]. In the relevant studies, many different terms are used to refer to the integration of science and mathematics, such as blended, connected, correlated, core, cooperation, coordinated, cross-disciplinary, fused, immersed, integrated, integrative, interactions, interdependent, interdisciplinary, linked, multidisciplinary, nested, networked, thematic, threaded, transdisciplinary, sequenced, shared, unified and webbed [32-38]. Some of these terms are used as if they were interchangeable. However, some of them have different meanings as a result of the different methods used for the integration of science and mathematics. As these terms are used in the studies dealing with the integration of science and mathematics, they may be included under the heading of integrated science and mathematics [32, 33, 38-40]. Using more terms naturally leads to a greater variance in the definitions developed for the integration of science and mathematics.

Berlin and White [41] defined the integration of science and mathematics as a technique in which scientific methods are used in a mathematics course while, at the same time, the methods of mathematics are employed in the science course, meaning that the two courses cannot be distinguished. Berlin and White [33] suggested that in order to decide whether or not science and mathematics are fully integrated, an independent person should observe the course. If s/he cannot distinguish the course as being either a science course or a mathematics course, then it can be said to be fully integrated. Lederman and Niess [35, 42], Roebuck and Warden [43] and Huntley [1] all defined the integration of science and mathematics as a situation in which science and mathematics are fully blended at a level to an extent where neither can be perceived as a separate discipline. Lehman [44], Frykholm ve Glasson [45] and Furner ve Kumar [46], on the other hand, focussed on the expansion of the naturally overlapping topics in science and mathematics in order to increase the connections between these two disciplines. These comprehensive perspectives lead to the question of whether an integrated scientific and mathematical curriculum can be implemented and realised.

1. 4. Towards an integrated programme of science and mathematics

Jacobs [47] proposed several ways in which the curricula could be integrated. One of the methods proposed by Jacobs is the parallel discipline design. According to this perspective, teachers should design the course in such a way that similar fields within the disciplines meet each other. Therefore, the content itself is not altered, as only its appearance is changed. Teachers do not intervene, except for the simultaneous organisation of the topics. This perspective is similar to the sequenced model as proposed by Fogarty [48]. In Fogarty's connected and shared models, it is argued that disciplines should be separate and that only when disciplines have similar points should connections be developed [49]. In the shared model, unlike the connected model, overlapping topics in separate disciplines are identified, whereby two disciplines deal simultaneously with these overlapping topics [48]. Vars [50] stated that such integrative approaches are the simplest versions of integration. Jacobs' and Fogarty's general views on curricula can be used for the cases of science and mathematics. However, there are other views which suggest the direct integration of science and mathematics.

Kren and Huntsberger presented three methods for the integration of science and mathematics: (a) teaching mathematical concepts first, and then using them in the science course; (b) familiarising the students with mathematical concepts in the science course and then presenting them in the mathematics course; and (c) the simultaneous presentation of scientific and mathematical concepts (cited [21]). Hurley [51] dealt with the integration of science and mathematics through a meta-analysis of the process of integration, and developed five categories of integration as follows: (a) sequenced integration, in which science and mathematics are taught sequentially; (b) partial integration, in which some topics in science and mathematics are taught in combination, while other topics are taught separately; (c) enhanced integration, in which either science or mathematics is chosen as the major discipline, and the other is taught in connection with the major discipline; (d) total integration, in which science and mathematics are taught together as equally important; and (e) parallel integration, in which the science and mathematics curricula are taught separately and simultaneously.

Hurley [51] and Kren and Huntsberger (cited [21]) also developed categories of integration that can be regarded as content-centred or content-based. One of the studies dealing with the organisation of content for the integrated curriculum emerged at the end of Cambridge conference [52]. Lonning and DeFranco [53], Huntley [54] and Roebuck and Warden [43], using this study, developed three models which are in fact very similar to one another. All three models include a similar continuum as shown in Fig. 1.

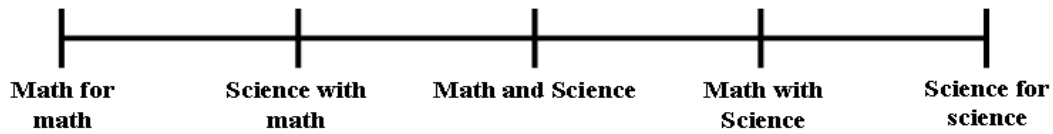

Fig. 1. Continuum included in the models.

As seen above, in the middle of the continuum, there is a category in which science and mathematics are totally blended. At the two opposing ends of the continuum, there are science and mathematics courses that exist independently without any connection between them. At the intervening points between the two ends and in the middle, there are two variances of integration in which either science or mathematics is at the centre and the other discipline is used as a vehicle. Lonning and DeFranco [53], Huntley [54] and Roebuck and Warden [43] developed models of integration which present cognitive possibilities on a continuum.

Davison, Miller and Metheny [55] developed five different types of integration, including content integration. These were: (a) discipline specific integration; (b) content specific integration; (c) process integration; (d) methodological integration, and (e) thematic integration. It can be argued that each step included in the model by Davison et al. [55] is consistent. However, they preferred to use only one of these integration categories in the model's implementation. Furthermore, the question remains as to how these categories may be used as an overall approach. Berlin and White [34] developed a model in which various aspects of instruction are taken into consideration.

Berlin and White's [34] BWISM (The Berlin-White Integrated Science and Mathematics) model includes six steps, as follows: (a) ways of learning; (b) ways of knowing; (c) process and thinking skills; (d) content/conceptual knowledge; (e) attitudes and perceptions, and (f) teaching strategies. The BWISM model provides very general background information with regard to the integration of science and mathematics. However, how content knowledge can be integrated and the positions of the disciplines in the integration process are not clearly given. Therefore, these points can be regarded as weaknesses of the BWISM model, given the integration approaches proposed by DeFranco [53], Huntley [54], and Roebuck and Warden [55]. On the other hand, it has several advantages over the other models of integration in terms of its focus on affective characteristics, skills, teaching methods and the aspects of measurement and assessment.

There are various views and models which deal with the integration of science and mathematics. It is commonly stated that there is no single view regarding the ideal integration [1, 13, 29]. Some researchers argue that studies regarding the integration of science and mathematics are still perceived as unclear [15, 56]. Therefore, the aims of this study are to clarify the existing studies concerning the integration of science and mathematics and to develop a theoretical model of integration to be used in Turkey where discipline-centred curricula are dominant in the implementation of teaching. This model will be proposed using the findings and views of previous studies. It can be stated that the model developed in this study is an alternative model of instruction for countries such as Turkey in which content is sometimes not adequately emphasised due to the use of centralised national examinations.

2. A new programme: The balance model

The studies by Berlin and White [34], Davison et al. [55], Lonning and DeFranco [53], Roebuck and Warden [43] and Huntley [1, 54] were introduced to middle school science and mathematics teachers as well as to student teachers at a university in 2007. The teachers were then asked to design and implement an integrated science and mathematics programme based on the findings of these studies. At the end of the implementation process, neither the teachers nor the student teachers had successfully developed an integrated programme. However, the participants' views of this process were collected [57, 58] and combined with the findings of previous studies, which helped us to develop the balance model featured in this study. Scientific and mathematical content was central to the preparation of this model. The mathematical and scientific content complemented the development of skills, teaching-learning processes, affective characteristics and measurement and assessment approaches in the balance model.

2. 1. Content knowledge

As previously stated, Lonning and DeFranco [53], Huntley [54] and Roebuck and Warden [43] all used a continuum in their models regarding content. In the balance model, however, balance replaces the continuum. As the model is an attempt to design a long-term curriculum, the balance between science and mathematics needs to be preserved. For instance, if a curriculum is designed for one year, the integrated curriculum should not favour science over mathematics. Balance should be achieved by giving an equal share of time to both disciplines in the process. The balance model was preferred, as it represents an equal integration of the content of both disciplines in this study (Fig. 2).

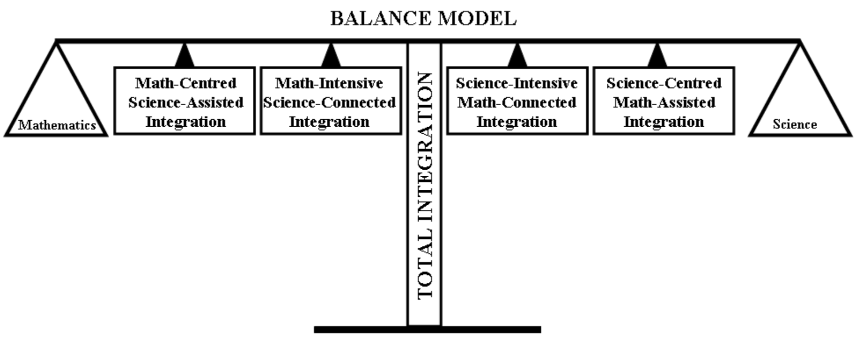

Fig. 2. Content knowledge for the balance model.

2. 1. 1. Mathematics

This is a course in which only mathematical outcomes are taken into consideration. At this level of the curriculum, integration is limited to in-class connections. The basic form of integration is the integration of mathematics and the activities of daily life. During this integration process, some scientific concepts can be transferred into the mathematics course without any attention being paid to the scientific curriculum. In other words, without aiming to improve any of the concepts, skills or outcomes included in the scientific curriculum, basic scientific skills and concepts can be used in the integration of mathematics and the activities of daily life.

2. 1. 1. 1. Mathematics-centred science-assisted integration (MCSAI)

This is an approach in which the mathematical outcomes are basic, and science is regarded as an interval discipline. The integration of science and mathematics can be achieved through the organisation of scientific and mathematical topics (parallelism, priority and secondary topics) so as to make it possible for the students to transfer these topics themselves. Mathematical outcomes can be reinforced by transferring scientific content at the appropriate points. The scientific content being transferred should preferably be taken from the scientific curriculum. However, other scientific content that is not included in the scientific curriculum can also be used to give examples from nature and daily life in the mathematics course.

2. 1. 1. 2. Mathematics-intensive science-connected integration (MISCI)

In this type of integration, mathematical outcomes are dominant. The connections between the content outcomes make the mathematics course closer to the science course. In terms of the transfer of content into the mathematics course, not only the prerequisites of the mathematics course but also those of the science course are taken into consideration. The outcomes that are to be learned simultaneously are identified. If the outcomes are suitable, the courses are simultaneously combined. During the planning phase, whether or not the mathematics outcomes to be acquired are the prerequisites of the future science outcomes is carefully considered. One of the aims of the course is the full acquisition of the mathematical outcomes at the end of the teaching-learning process. However, although the scientific content of the course is intense, the aim is not the students' acquisition of the full outcomes of the science unit.

2. 1. 1. 3. Total integration (TI)

In total integration, the target is to devote an equal share of the integrated curriculum to science and mathematics. Neither of the courses is regarded as the core of the curriculum. This course can be called either science-mathematics or mathematics-science. Separate science or mathematics outcomes do not exist. An independent person observing the course cannot recognise the course as a purely mathematical or a purely scientific course. One of the aims of the course is to help the students to acquire all of the outcomes of the science course as well as the mathematics course.

2. 1. 1. 4. Science-intensive mathematics-connected integration (SIMCI)

In this type of the integration, the focus is the outcomes of the science course. The science course becomes closer to the mathematics course through the connections between the content outcomes. Both the scientific prerequisites and the mathematical prerequisites are taken into consideration through their transfer into the science course. The outcomes to be learned simultaneously are identified. If the outcomes are suitable, the courses are simultaneously combined. During the planning phase, whether or not the science outcomes to be acquired are the prerequisites of the future mathematics outcomes is carefully considered. One of the aims of the course is the full acquisition of the scientific outcomes at the end of the teaching-learning process. However, although the mathematical content of the course is intense, the aim is not the students' full acquisition of the outcomes of the mathematics unit.

2. 1. 1. 5. Science-centred mathematics-assisted integration (SCMAI)

This is an approach in which the scientific outcomes are basic and mathematics as a discipline is regarded as an interval discipline. The integration of science and mathematics can be achieved through the organisation of mathematical and scientific topics (parallelism, priority and secondary topics) in such a way as to make it possible for the students to transfer the topics themselves. The outcomes of the science course are reinforced by transferring mathematical content at the appropriate points. The mathematical content which is transferred should preferably be taken from the mathematical curriculum. However, other mathematical content that is not included in the mathematical curriculum can also be used to give examples from nature and daily life in the science course.

2. 1. 2. Science

This is a course in which only the outcomes of the science course are taken into consideration and regarded as basic outcomes. At the level of the curriculum, integration is limited to in-class connections. The basic form of integration is the integration of science and the activities of daily life. During this process of integration, some mathematical concepts can be transferred into the science course without any attention being paid to the mathematical curriculum. In other words, without aiming to improve any of the concepts, skills or outcomes included in the mathematical curriculum, basic scientific skills and concepts can be used in the integration of science and the activities of daily life.

The traditional discipline-centred approach to the curriculum advocates that the content of the separate disciplines be taught separately in class, and when that when necessary outside of school, students can use the topics they have learned [11]. Teachers transfer the course content completely within the predetermined time period. It has been concluded that students in the US taking courses in which progressive instruction was used in a democratic school climate were deficient in terms of their knowledge of the course content. In addition, it was found that their level of achievement in examinations was lower than that of other students in different countries where a traditional discipline-centred curriculum was implemented before the Second World War [60, 61]. There are certain reasons for a lower degree of commonality in the integrated curriculum, such as missing content knowledge from the various courses or losing emphasis on certain topics. However, some educational researchers who have recognized these drawbacks argue that integration can be achieved while keeping the content knowledge and standards of the disciplines as they are [25, 29, 47, 62]. The balance model also shares this view and one of its ultimate goals is to keep the content outcomes in their original form.

Meier et al. [28] argued that teachers should not only focus on the similarities between the science and the mathematics courses, but should also be aware of the differences between them. Therefore, both sides of the balance model take this sensitive subject into consideration. It predicts that unsuitable parts of both courses should be taken into consideration during the planning phase, so that the differences between the courses can be emphasised and these differences can also be placed on the sides of the balance. In the discipline-specific integration model by Davison et al. [55], in-class connections are regarded as significant. The balance model also pays attention to in-class connections as well as intercourse connections. In this regard, it is consistent with the assumptions of Davison et al. [55]. Berlin and White [41] emphasised that making the disciplines too close may lead to significant philosophical, methodological and historically distinctive points being missed. Therefore, the balance model regards the steps outside of the integration of science and mathematics as components of the integration process. It also pays attention to the negative side effects of attempts at total integration. It attempts to achieve partial integration without eliminating the differences between science and mathematics in SCMAI while taking into consideration the steps of the MCSAI. Thus, the basic characteristics of science and mathematics remain in their original form in these steps.

The other feature of this model is that it considers the differences between theory and practice. Generally speaking, identifying a point in a continuum remains does not progress past a theoretical attempt. Developing and implementing a curriculum based on a predetermined point in the continuum is generally not possible. The integrated scientific and mathematical curriculum, when it is implemented, appears to be at the left or right sides of the predetermined point in the continuum [1, 43, 54]. Therefore, the content of the balance model includes, not a predetermined point, but an interval and entities moving within this interval. During the description phase, it is estimated that integration will occur between the points and a full description can be realised using this possibility. For instance, a curriculum could be designed between the mathematical and MCSAI points. In this case, the practitioner may name his curriculum based on his view of which point it is closest to. Alternatively, it could be stated that the curriculum occurs at the mid point of the two courses. If a curriculum is between SIMCI and TI, and if it is closer to TI, it is called total integration (and vice versa).

MISCI and SIMCI are the results of designing curricula over long periods. Sometimes it is necessary for the goals of a course to be set immediately. In this case, the other course included in the integration process may be taught later on. Thus, the goals of one course are fulfilled, whereas the goals of the other course may be cancelled. A strong sense of pre-learning can be regarded as a goal of instruction. However, sometimes a curriculum that was developed for the purposes of total integration can be regarded as mathematics-intensive or science-intensive. These sub-steps are significant in that they indicate the available options other than total integration. However, the balance model attempts to achieve total integration at the points where the goals of the two courses can be properly combined. Similarly to Lonning and DeFranco [53], Roebuck and Warden [43] and Huntley [54], it focuses on the value and priority of total integration.

2. 2. Skills

The skills dimension of the balance model was developed according to the mathematical and scientific skills included in the sixth, seventh and eighth grade curricula of MEB. The scientific skills included in these curricula of the MEB [17] are given in Fig. 3.

Some of the mathematical skills are taken from the mathematical curriculum of the MEB [63]. These are problem solving, reasoning, communication and forming connections. NCTM [14], on the other hand, includes the skill of representation as well as these skills. Therefore, the mathematical skills are as follows (Fig. 4).

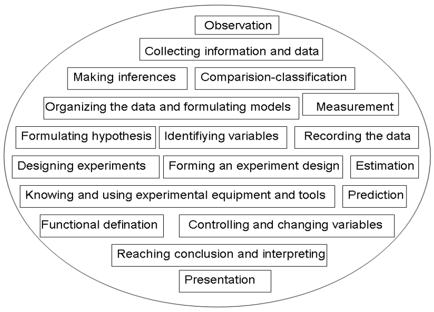

Fig. 3. Skills of science and technology course in the 6th, 7th and 8th grade curricula of the MEB.

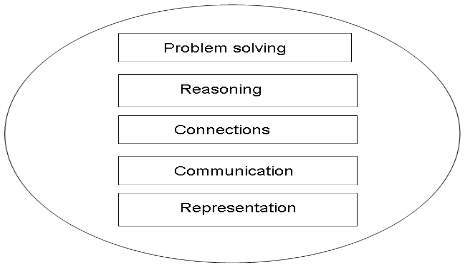

Fig. 4. Skills involved in the mathematics courses in the 6th, 7th and 8th grade curricula of the MEB and NCTM.

The skills which are common to both courses can be developed as they are used in both courses. In developing the common skills of the model, the mathematical skill of communication and the scientific skill of presentation are combined under the heading of communication, as both skills refer to the same concept. Furthermore, the mathematical skill of representation and the scientific skills of data processing and model development are combined under the heading of data processing and model development, as once again these two skills refer to similar concepts. The balance model divides these skills into two subgroups, namely primary skills and secondary skills (Fig. 5).

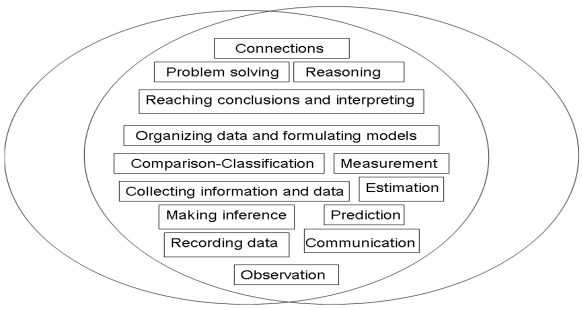

Fig. 5. Common skills that are regarded as primary.

The primary common skills include all mathematical skills and frequently used scientific skills. The secondary common skills, on the other hand, include all mathematical and scientific skills (Fig. 6).

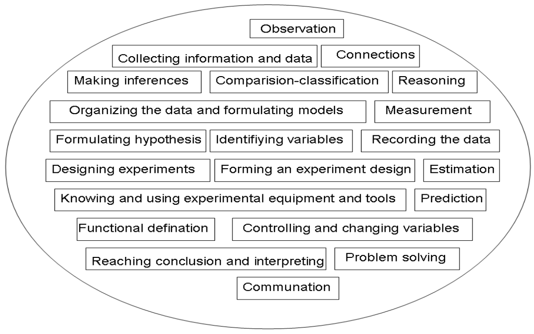

Fig. 6. Common skills that are regarded as secondary.

Mathematical skills are improved in both courses [31]. In the studies dealing with the role of skills in the integration of science and mathematics [28, 43], common primary skills (or at least some of them) are called common skills. Such descriptions may be a result of the view that simple connections between science and mathematics can be seen as the integration of these two disciplines. On the other hand, the ease of developing simple connections between two courses and the fact that these connections are mostly natural make the improvement and implementation of primary skills easier.

The balance model considers mathematical skills as common skills which are independent of the integration approaches adopted in their implementation. The reason for dividing skills into two subgroups is the scientific skills. More specifically, some scientific skills may be included in the mathematics course. However, this is not very common in practice. Generally speaking, the scientific skills of observing, predicting, estimating, measuring, collecting data and information, recording data, organizing data and formulating models, interpreting and inferring, communicating, concluding, comparing and classifying are reinforced and improved as well as being frequently used by mathematicians [31]. Therefore, these skills, together with mathematical skills, can be regarded as common skills in the integration of science and mathematics. In discovery/inquiry-based mathematics courses, it is common to use simple materials which are easy to develop and use. In the science course, on the other hand, both simple experiments and more complex ones requiring the use of a laboratory are included [17]. Thus, most of the primary common skills outlined above are used and improved upon in the science and mathematics courses.

An integrated scientific and mathematical curriculum can be achieved either by developing connections between these two courses or by fully integrating them. If the integration method is adopted, experiments can also be used in mathematical activities and in the mathematics course. Therefore, it is possible to argue that each experiment or activity begins with a problem and a hypothesis that contains a temporary solution for the problem [34, 64]. This method improves students' skills, including collecting information through experimentation in the mathematics course. If the problem and the hypothesis are identified, the students will begin to use their skills of identifying the variables, controlling and changing them. Then, the skills of organizing the experiment and its design need to be incorporated into the process. In mathematics tuition, in which experimentation and/or activities are regarded as basic entities, the skills of being familiar with experimental tools and equipment as well as using them naturally are improved in the process. These skills become prior common skills in an integrated approach in which the borders of science and mathematics disappear. In the fully integrated approach, all of the skills involved in the scientific process can be accepted as common skills for the courses of science and mathematics [34]. On the other hand, the balance model divides the skills to be improved into two subgroups (primary and secondary skills) based on the integration category adopted. For the category of MCSAI, the skills of SCMAI are regarded as primary common skills, while for the SIMCI, MISCI and TI, these are regarded as secondary common skills.

Most studies have indicated that integration is only possible in regard to skills, and most studies focus on skills [13, 30, 49, 55]. Those who have adopted this view aim to improve problem solving and scientific processing skills, and consider the course content as merely a vehicle for the improvement of skills. The balance model is not consistent with this view. Instead, it argues that skills should complement the content in order to be improved. In this sense, teachers may encounter difficulties in developing the curriculum and instructional materials. However, their achievements would be greater. The most significant outcome is the elimination of the possibility that students will acquire incomplete content knowledge.

2. 3. The processes of teaching and learning

The integrated scientific and mathematical curriculum regards the mathematics course as an experimental or quasi-experimental discipline, like the science course, in which the processes of discovering, finding and experimenting are also used for collecting information. This requires the use of the same instructional methods, techniques and strategies in both courses. The process of teaching-learning is designed following the principles of the constructivist approach. The teaching-learning process is organised based on the view that the teaching-learning process in the science course affects that of the mathematics course, and vice versa. The teaching methods, technique and strategies to be employed are determined taking into consideration the options of either transferring content and skills from the other course or totally integrating the two courses.

This assumption of the balance model is consistent with the views presented in the relevant research. Due to the fact that the mathematics course, like the science course, allows for the adoption of a constructivist approach to teaching [8, 65-68], in the integrated science and mathematics curriculum, a teaching-learning process that is suited to the constructivist approach and in which students are active participants in the process can be used [15, 25, 34, 64].

Some researchers argue that the only possible way in which to achieve integration is through the use of instructional methods and techniques [6, 30, 55, 69]. However, the balance model follows the ways in which the content and skills are first identified and the teaching methods that are consistent with the constructivist approach are selected. In other words, the instructional method is the determining factor for the integration category to be used. Instead, the instructional method is one of the significant vehicles with which to achieve the integration type which is adopted for implementation.

2. 4. Affective characteristics

Previous research has indicated that there is a significant relationship between achievement in the fields of science and mathematics and the affective characteristics of the students [70-72]. The balance model assumes that there are various and numerous factors affecting the learning of science and mathematics and that these factors have interrelated effects. One such factor is the affective characteristics of the students. The balance model assumes that when the curriculum is implemented, scientific achievement is not only affected by the affective characteristics which are related to scientific achievement or learning, but also by the affective characteristics which have an effect on mathematical achievement or learning. The same is also true for achievement and learning in mathematics. When science and mathematics are successfully integrated, students' anxiety about mathematics may affect their scientific learning and vice versa. This influence is not limited to the anxiety about mathematics or self-efficacy in the field of science. It is observed in all affective variables, such as self concept, interest, attitude and motivation in both science and mathematics. These cross effects can dominate the total integration, while these effects may occur less in SCMAI or MCSAI. Therefore, practitioners should be aware of not only the contents and skills involved in both courses, but also of the affective characteristics of the disciplines, in order to implement the integrated scientific and mathematical curriculum successfully.

These affective characteristics may have positive or negative effects on the integrated curriculum. It is well-known that the affective characteristics of students in regard to the course content to be learned have significant effects on their learning and achievement. When the courses are integrated, it is difficult to predict the interaction of the affective characteristics. Kiray [8] concluded that some students either like or dislike the integrated scientific and mathematical curriculum based on their previous affective attitude towards either of the courses. However, other students previously like one these courses, and their attitude towards the integrated scientific and mathematical curriculum is positive. On the other hand, there are also students who dislike one of the courses but like the other, who reported that they lost interest in the integrated course. Singh et al. [73] suggested that curricular or co-curricular activities related to science and mathematics should be used in order to improve the student's motivation towards their courses. Related studies have also argued that affective variables of science and mathematics courses should not be analysed in terms of linear relationships. The balance model argues that teachers should be informed about the students' affective characteristics in regard to their science and mathematics courses before implementing the integrated scientific and mathematical curriculum. Berlin and White [33] stated that affective characteristics (such as attitudes) belonging to either of the fields of science and mathematics can influence those of the other. The balance model accepts this view. Therefore, it emphasises that designers and practitioners of the integrated curriculum should not ignore the importance of affective characteristics.

2. 5. Measurement and assessment

Measurement and assessment cannot be dealt with independently from the teaching-learning process. An integrated science and mathematics curriculum in which a constructivist approach is adopted should include a process of measurement and assessment that is consistent with the principles of the constructivist approach. Therefore, a measurement and assessment procedure in which not only content knowledge but also process is evaluated should be employed. Based on the category of integration which has been adopted, science and mathematics teachers may carry out the measurement and assessment process separately or collaboratively. When TI is used, the criteria for measuring and assessment should be common for mathematics and science. On the other hand, if the SCMAI is preferred, the criteria developed for the science course may contain significant criteria for the mathematics course. For instance, the skills of the four major mathematics activities, problem-solving or ratios can be included in the measurement and assessment criteria. In the SIMCI category, on the other hand, the criteria for mathematics may be included at higher levels. However, the rate of the mathematical criteria should not exceed the rate of the scientific criteria. Although the balance model does not totally reject the traditional methods of measurement and assessment, it also employs alternative and authentic methods, as it is also an attempt to create a process of assessment. It requires that all of the predetermined goals of the instruction process should be completely measured at the end of the curriculum implementation. The balance model is consistent with the views of Berlin and White [33] and Czerniak et al. [13] regarding the fact that an integrated science and mathematics curriculum should contain alternative and authentic measurement and assessment techniques. However, since such assessment techniques do not exist, they should be developed either by the programme's designers or by practitioners.

3. Conclusions and implications

Although the interaction between mathematics and science was first recognised a long time ago, teachers cannot reflect this close relationship under the current curriculum. One of the reasons for this disability is that a discipline-centred curriculum is dominant [1, 29, 74, 75]. Teachers have to limit themselves to the science course or the mathematics course due to the current curricula. Therefore, they may feel that they are unable to teach the other course [2, 74, 76]. The balance model takes this fact into consideration and offers the teachers a variety of integration options. Teachers who use the SCMAI and MCSAI models, which can be regarded as simple versions of an integrated curriculum, may improve their self-efficacy and achieve total integration over time.

There are several studies suggesting that quality improvement in the education of science and mathematics is possible with various methods and techniques of teaching [77-83]. Nevertheless, this study revealed the importance of integrated program design. There are a few experimental studies on the integration approach. Most of these studies involved asking teachers to develop and implement an integrated science and mathematics curriculum. The other practice regarding an integrated curriculum involves teachers or student teachers being given the general heading of "science and mathematics integration" and then asked to develop and implement an integrated curriculum based on their own understanding. In such practices, teachers and student teachers cannot achieve the goal of developing and implementing an integrated curriculum due to their deficit of theoretical knowledge about the subject. The balance model has been designed in order to explain the process and related processes in detail to the teachers as well as to student teachers. The advantageous dimension of the model for teachers is that it allows the curriculum to be designed over a long period of time. Thus, instead of acting immediately, teachers may have longer periods of planning.

As the balance model does not ignore content-specific knowledge, a significant disadvantage for the implementation of the curriculum in countries (including Turkey) in which centralised examinations are frequent is eliminated. Therefore, parents' anxiety will also be eliminated as the content is studied in full. As the model meets the expectations of both parents and educational institutions, teachers can employ the model easily.

It could be suggested that teacher training institutions may employ the balance model in order to teach student teachers how to integrate science and mathematics as well as the related content, skills, affective characteristics, teaching methods, assessment methods and approaches. Training teachers using this model may contribute to the common usage of an integrated scientific and mathematical curriculum.

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