行政院國家科學委員會專題研究計畫 期末報告

數學與其他知識領域的關係：課程問題發現與解決

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 101-2511-S-004-001-
執 行 期 間 ：101 年 08 月 01 日至 102 年 09 月 30 日
執 行 單 位 ：國立政治大學教育學系

計 畫 主 持 人：邱美秀

計畫參與人員：碩士班研究生-兼任助理人員：詹欣怡

報 告 附 件 ：出席國際會議研究心得報告及發表論文

公 開 資 訊 ：本計畫可公開查詢

中 華 民 國 102 年 10 月 27 日

中 文 摘 要 ： 這項研究的目的是找出數學和物理間不協調之課程實施的議題。數學和物理之間的不協調發生在 2010 年的高中課程。11 年級選理組的學生在學習物理的二維運動之前沒有學習有關三角的數學課程。本研究訪談 3 位課程開發者、22 位數學和物理教師、2 位校長、45 位理組學生。質性分析的結果顯示：在國家、教師、學生三層面課程的重大議題分別為領域界限、固定課程、多樣發展。不協調的課程增加教育不平等，特別是不利於非高成就、低收入的理組學生。此結果顯示：科學教師可以增加跨素養的能力以彌補此未協調之課程；但是，最好的解決辦法仍然是由「階層民主」的課程開發流程改變為「以平等的教授和老師的課程來支持學生課程」的「理性民主」。

中文關鍵詞： 課程改革；學習；數學課程；物理課程；教學

英 文 摘 要 ：

英文關鍵詞：

Issues in implementing an incoherent curriculum between mathematics and physics

Abstract

The aim of this study is to identify issues in implementing an incoherent curriculum between mathematics and physics. Incoherence between mathematics and physics saliently occurs in the high-school curriculum of 2010 in Taiwan. Grade 11 science students study 2-dimensional motion in physics without any prior learning experiences of trigonometry in mathematics. The perspectives of 3 curriculum developers, 22 mathematics and physics teachers, 2 principals, and 45 science students were obtained by interview. The results of qualitative data analysis reveal that the major issues of the incoherent curriculum at the national, teacher, and student levels are domain boundaries, fixed curriculum, and diverse development. The incoherent curriculum increases educational inequality in failing non-high-achieving and low-income science students. The findings suggest that science teachers can increase transliteracy to remedy the incoherent curriculum. The best solution, however, is still to transform the curriculum development flow based on 'hierarchical democracy' to a new framework, with equitable professor and teacher curricula to support student curricula based on 'rational democracy'.

***Keywords**:* curriculum reform; learning; mathematics curriculum; physics curriculum; teaching

Introduction

A coherent curriculum design is essential to providing basic education. This is particularly true between mathematics and physics. Physics teachers in both high school and higher education tend to see student mathematics competence as the basis for successful physics learning (Angell, Guttersrud, Henriksen, & Isnes, 2004). Mathematics curriculum also calls for external connections with life (Askew, Venkat, & Mathews, 2012; Szendrei, 2007). Incoherence between mathematics and physics curricula, however, saliently occurs in the Taiwan 2010 high school curriculum. Grade 11 students choosing the science course package study 2-dimensional motion and dynamics in physics without any prior learning experiences of trigonometry or trigonometric functions in mathematics. The traditional curricular flow, from national-intended, teacher-implemented, to student-received curricula (Figure 1), fit the practices of most educational systems, as revealed by the Trends in International Mathematics and Science Study (International Association for the Evaluation of Educational Achievement, 2005). Students, however, may inevitably become the sacrifices by being placed at the bottom of the flow.

<Insert Figure 1 around here.>

Mathematics and science education is not only a cognitive issue but also an affective, socio-cultural, and political one (Jablonka, Wagner, & Walshaw, 2013). This study was conducted from 2011-2013, the first 2 years of the implementation of the incoherent curriculum. The incoherence between mathematics and physics in the 2010 high school curriculum reform is likely to increase the disturbance at the national, teacher, and student levels. As such, this study aims to document the historical event, which may provide valuable experiences for future science curricular designs.

The traditional curriculum development flow

The traditional curriculum development process is based on 'hierarchical democracy' flowing from the national, teacher, to student levels in curricular design and implementation (Figure 1). The flow is based on the conception that academic disciplines precede school subjects, failing to distinguish the roles of professors as experts in content knowledge and school teachers as experts in pedagogical content knowledge (Deng, 2007). For example, in order to develop a coherent science and technology curriculum for the Netherlands, Geraedts, Boersma, and Eijkelhof (2006) suggest a curricular decision-making framework going from the macro/state level (including the Ministry of Education, institutions, and publishers), the meso/school level (including school and departments), to the micro/classroom level (including teachers and students).

The traditional curriculum development flow inevitably creates gaps between the national and teacher curricula, which in turn may create problems in student curricula. Burny, Valcke, Desoete, and Van Luit's (2013) study shows that curriculum sequences may not be the same across countries, and some contents can be learnt at earlier stages without being at the expense of learning outcomes. Cross-domain links, especially cross-domain coherence between sciences, appear to be a political issue relatively rarely researched in science education but may have an important influence on student learning sciences.

Coherence of curricular design between sciences

Mathematics and science concepts, tools, and activities can be integrated in different degrees in mathematics and science teaching. As revealed by Lonning and

DeFranco (2010)'s theoretical model, which indicates that mathematics and science can be integrated with varying degrees of focus from independent mathematics, mathematics focus, balanced mathematics and science, science focus, to independent science.

Can a coherent curriculum design between different domains of knowledge be achieved? Geraedts et al. (2006) believe that a coherent science and technology curriculum may be achieved by considering the nature of the disciplines and student experience of uninterrupted learning. Mathematical objects and operations tend to be basics for student understanding of mathematical functions in science concepts. For example, proportional knowledge, skills, and reasoning are a basis for full student understanding of ph values in the advanced high school chemistry curriculum (Park & Choi, 2013). The collaboration between mathematics and science appears to be a necessary measure for successful science education.

The problem context

The national curriculum is mainly centralized and designed by the Ministry of Education in Taiwan (Huang, 2012). The new national curriculum for high school formally launched in 2010. The curriculum was developed following the traditional curriculum development process, as seen in Figure 1. The major contents of the curriculum were designed by scholars of domain-specific academic disciplines, normally from higher education.

The curriculum allows Taiwanese Grade 11 students who choose the science course package to study 2-dimensional motion and dynamics in physics without any prior learning experiences of trigonometry. Table 1 shows the contents of mathematics and physics topics that science students are taught in the 3 phases of the first semester of Grade 11. Slightly later in the process of curriculum design, private publishers gradually began to design and publish textbooks and related teaching and learning materials based on the curriculum.

<Insert Table 1 around here.>

Teachers teach the topics and follow the schedules predetermined by the national curriculum although the general part of the curriculum provides some space for schools to fit the curriculum to school contexts. The limitation of teachers' authority to change topics and schedules results in tight schedules. Cram schools and private schools are likely to pre-teach students to supplement the mathematics knowledge and skills needed for learning about 2-dimensional motion in physics due to the incoherent curriculum. Cram schools are popular private educational industries in Taiwan, aiming to enhance student achievement scores in school tests and university entrance examinations. Private and cram schools reflect Taiwanese parents' expectations of early and intensive preparation for academic success for their children (Tsai & Kuo, 2008).

The present study

The incoherent design of the new national high school curriculum formally implemented from 2010 in Taiwan is likely to increase the disturbance of teaching and learning in the real educational context. This study, therefore, aims to understand the issues in the national-intended, teacher-implemented, and student-received curriculum levels by answering the following research questions.

1. What are the issues in the national intended curriculum level as perceived by curriculum developers and understood by teachers and students?
2. What are the issues in the teacher implemented curriculum level as perceived by mathematics and physics teachers and understood by students and professors?
3. What are the issues in the student received curriculum level as perceived by students who aim to study sciences in university and understood by professors and teachers?

Method

Participants

The research participants were 3 curriculum developers, all of whom are professors in higher education, and 12 mathematics teachers, 10 physics teachers, 2 principals, and 45 Grade 11 science students (25 girls, 20 boys) in the high schools of Taiwan. The students were the first cohort formally experiencing the new 2010 high school curriculum since their Grade 10. This study was conducted in Grade 11 during the 2010 academic year (August 2010 to July 2011), when they had formally chosen to study a multidisciplinary science ‘package’ course mainly aiming to study sciences (including engineering, mathematics, medicine, national sciences, technology, etc.) in higher education.

In the present system, Taiwanese high school students can choose to study one package of courses from three choices: humanities and social sciences (Package 1), physical sciences (Package 2), and physical and biological sciences (Package 3).

Grade 11 students choosing Package 2 or 3 courses (i.e., 'science students' in this study) formally confront the incoherent curriculum between mathematics and physics. They are taught advanced physics that needs more use of mathematics knowledge and skills to quantify physics knowledge (Table 1). The students choosing Package 1 courses study basic physics, which emphasizes a qualitative understanding of physics knowledge and will not confront the problem of incoherence between mathematics and physics curricula.

Data collection

The research participants were interviewed individually by 1 professor, 7 high school teachers, and 6 research assistants trained in the interview procedures. The participants were asked different guiding questions in the interview. The curriculum developers were interviewed with the following guiding questions.

1. What do you think about the relationship between physics and mathematics?
2. What do you think about the relationship in curriculum between physics and mathematics?

The mathematics and physics teachers were interviewed with the following guiding questions.

1. What are your perceptions, concerns, and teaching methods for the past and present (2010) curricula you experience as a mathematics/physics teacher?
2. How related are mathematics and physics (10 = very high - 1 = very low)?
3. How related are mathematics and physics in teaching (10 = very high - 1 = very low)?
4. What are your responses and your students’ responses to the incoherence between the present mathematics and physics curricula (i.e., students learning physics without some necessary mathematics knowledge or skills)?

The students were interviewed with the following guiding questions.

1. Do you know that students studying Packages 2 and 3 (science-focused) courses will learn physics without some necessary mathematics knowledge or skills in Grade 11? To what extent do you understand this? How do you know this?
2. What are your opinions about this?
3. How do you, your classmates, and your teachers solve this problem?
4. How related are mathematics and physics (10 = very high - 1 = very low)? Please

give your reasons for your answer. What mathematics knowledge do you need when you learn physics?

The participants were asked to provide answers to the above guiding questions. They were also asked follow-up questions to clarify their answers until the full picture had been developed. The interviews lasted from 20 to 70 minutes and audio was recorded.

Data analysis

The interviews were fully transcribed into verbatim transcriptions. Qualitative data analysis methods were used to analyze the transcriptions (Charmaz, 2000; Corbin & Strauss, 1990; Marton, 1981; Miles & Huberman, 1994; Strauss & Corbin, 1990, 1998). The data analysis focused on their responses to the national, teacher, and student curricula, respectively, and the themes were gradually identified through the iterative process of open coding, constant comparison, and theme finding.

Results

Professors, mathematics teachers, physics teachers, and students show different responses to the incoherent curriculum between mathematics and physics at the national-intended, teacher-implemented, and student-received curriculum levels. Table 2 summaries the results. Principal interviews were used to clarify some issues in relation to teacher curriculum raised in the data collection and analysis process, and are not included in Table 2.

<Insert Table 2 around here.>

Issues at the national-intended curriculum level

At the national curriculum level, the issue is domain boundaries. Mathematics emphasizes abstraction, procedures, and theorems, while physics emphasizes scientific advances, concepts, and unified truth. The following sections include excerpts from the interviews that address the research questions given above. Basic demographic information is included for each respondent.

Curriculum designer perception of the national curriculum

Professors have the conception of clear boundaries between their and the others' fields in the academic world.

- Mathematics is the language of physics. … Physicists use mathematics to describe their phenomenon. Purely mathematical reasoning is supposed to have no direct relationship with the real world, … but it lets physicists see the likely physical meanings. … The most famous example is Einstein. Later experiments prove he's right. … String theory is downright mathematical and up to now there is still no direct evidence of any physical reality. … Mathematics is obviously just separated from reality, but its reasoning is often right. (Male, professor of mathematics in higher education)

- Physics, including other disciplines, see mathematics as a tool, but mathematics itself has its own mathematical thinking and beauty. (Female, professor of mathematics and mathematics education in higher education)

A professor in the vocational education field gave few opinions regarding the mathematics and physics curriculum but instead focused on his own understanding.

- I don't know [about the incoherent curriculum between mathematics and physics]. … [Based on my experiences of participating in the national curriculum design of vocational education,] professors determine the curricular framework, teaching contents, and credit hours. Although there are forums for the public and school teachers to give their voice, basically the curriculum has been pre-determined and decisions have been made about how to implement the curriculum. So, the effect of the forum is not big. (Male, professor of vocational education in higher education)

Teacher perception of the national curriculum

The difference between mathematics and physics teachers is that mathematics does not need physics and mathematics teachers tend to simplify the problem of the incoherent curriculum. On the other hand, physics needs mathematics. Physics teachers have serious concerns about the incoherent curriculum.

- The relation between mathematics and physics is around 6 [Scale 1 - 10]. When students ask why they must learn such difficult mathematics, I say that physics uses mathematics. For instance, vectors come from physics, but I can only tell students the characteristics of vectors and how to calculate them and cannot say how vectors are related to physics. I think that if students are good at mathematics, they will feel that learning physics is easier. (Female, mathematics teacher, age 36, teaching year 13, south Taiwan, id t24)

- The relation between mathematics and physics is around 7 [Scale 1 - 10]. … Their relation is built based on 'mathematical skills'. … Perhaps physics teachers can change the order of teaching content by talking about things not so related to mathematics, such as sound waves and electric resistance. (Male, mathematics teacher, age 45, teaching year 19, south Taiwan, id t33)

Physics teachers view mathematics as its mother, hoping mathematics can look after physics. Physics, on the other hand, has strong identity, confidence, and independence in its own power and tends to take these for granted. The physics curriculum appears to ask teachers to teach many (advanced) physics contents, which increases physics teacher stress in completing the teaching contents on time.

- I think mathematics and physics are the same subject. … Mathematics is the language of physics. [It is her] first language, her native language. If you let students learn their mother tongue so late, how can they learn physics? … Engineers are the basis of our country. Physics is the basis of engineering. Mathematics is a tool, prepared for other subjects, and cannot be changed without thinking of the others. What mathematics destroys seriously is: Mathematics is 'not' a science. … Mathematics is not in the same field as physics [in terms of this incoherent curriculum]. … The professors designing the physics curriculum said that physics itself would solve the problem [of the incoherent curriculum]. (Male, physics teacher in high school, age 38, years of teaching 14, north Taiwan, id t01)

- Physics and mathematics are almost the same and cannot be separated. … Physics has its content sequence in terms of its historical development and so its teaching sequence cannot be changed. … We do not have extra time for teaching physics-related mathematics [e.g., trigonometry] because the physics curriculum expects us to teach many new things, such as nanotechnology and astrophysics for Grade 10. The time for teaching physics to Grade 11 science students is reduced. Three chapters originally placed in Grade 11 have been moved to Grade 12, which is a large amount of content. There is no time provided by the physics curriculum to teach [physics-related mathematics]. It should not be our [physics teachers'] job to teach mathematics. (Male, physics teacher, age 51, teaching year 24, north Taiwan, id t03)

The domain boundary between mathematics and physics appears to be more salient for mathematics teachers than for physics teachers.

Student perception of the national curriculum

Science students tend to see mathematics as the major basis for learning physics. They have very negative responses to the incoherent curriculum.

- Mathematics affects physics. If you are not good at mathematics, then it [physics] will die a tragic death. … Grade 10 may be good time for teaching trigonometry [in mathematics for learning physics more easily]. … I am thinking whether or not I could learn trigonometry well if trigonometry were taught in junior high school. One semester earlier to learn trigonometry could be good. (Female, high-achieving school, north Taiwan, id ss19)

- The curriculum sucks. I am experiencing it now. It's really bad because physics can’t be taught in detail, and I can only memorize it. Mathematics repeats it again in detail, but I forget how it [mathematics] is used in physics because when I learn physics, I learn by memorizing the related mathematics. (Male, middle-achieving school, north Taiwan, id sp02)

Issues at the teacher implemented curriculum level

At the teacher curriculum level, the issue is fixed curriculum. Although the national curriculum allow some small spaces for schools to fit curriculum to their contexts, the socio-cultural atmosphere appears to preclude the possibility of fitting the national curriculum to public schools.

Teacher perception of the teacher curriculum

Mathematics teachers feel relaxation and independence given the narrower and self-contained content, while physics teachers feel anxiety and helplessness given the wider content and insufficient mathematics ‘tools’ for physics.

- The relation between mathematics and physics may be 8 [scale =1 – 10] from the perspective of the development of mathematics and history. Newton is both a physicist and mathematician. … However, from the perspective of teaching practice, the relation between mathematics and physics is very low, only 2 [on the same scale]. We separate mathematics and physics into different worlds. Otherwise, the two kinds of teachers will think that we are robbing the others' things. When mathematics has taught something, physics teachers will think whether or not they have to teach it. If physics has taught mathematics, mathematics teachers will think whether I should teach this in detail or quickly, as students should have already learned this. (Male, mathematics teacher, age 29, teaching year 5, north Taiwan, id t04)

- We discuss with our mathematics colleagues [whether or not it is possible to move the teaching of trigonometry and vectors to one-term earlier], but the conclusion is 'no'. The director of mathematics teachers or mathematics teachers worry that they will be sued ... by parents and, in fact, cram schools[, if they fail to obey the curriculum]. (Male, physics teacher, age 38, teaching year 14, north Taiwan, id t01)

Student perception of the teacher curriculum

Teachers in the public school tend to strictly follow the national curriculum. Private schooling and gifted education generally give students opportunities to learn more content at earlier stages.

- Our school physics teachers will explain a bit of the content of trigonometry. Some just directly ask us to memorize the formulas [of trigonometry]. Adjusting the chapters will make the teaching [of mathematics and physics] more smooth (Male, community school, south Taiwan, id ss03)

The following two excerpts show how public schooling fails students who can only rely on public schools and how cram and private schooling give their students privileges in the implementation of the incoherent curriculum.

- I knew [that we would learn physics without sufficient mathematics learning] during the Grade 10 summer holiday. … The cram school physics teacher first taught a lesson for trigonometric functions. I still went to cram school mathematics, and it taught trigonometry as well. Then, the school term began. Mathematics class taught trigonometry, almost at the same time [that physics used it]. … The school physics teacher just started with some special angle triangles like 3-4-5 triangles. The physics teacher said that when mathematics taught trigonometry, then he would begin to use it. … I felt OK. … but I wouldn't have felt OK if I had not been to cram school [during the Grade 10 summer]. (Female, high-achieving school, north Taiwan, id ss19)

- Our physics teachers always thought that we had learnt some [mathematics] when they taught [physics], but actually, we hadn't. Then, physics teachers spent a little time to teach mathematics concepts and formulas that were used in physics. … We only learnt the first three trigonometric functions [i.e., sine, cosine, and tangent]. So, when a physics problem needed to use the last three [i.e., cotangent, secant, and cosecant], physics teachers used the first three [trigonometric functions] to represent them. I like physics, and so I had learnt some related mathematics in junior high school. As such, I understood more. (Female, private high-achieving school, and Grade 7-12 school, central Taiwan, id ss04)

Curriculum designer perception of the teacher curriculum

Professors perceive themselves as having weak control over teachers' implementation of curriculum. They can only define the 'content' of the curriculum. Teachers and schools have the authority to teach what they want.

- I agree that trigonometry needs to be taught before related physics topics. However, mathematics content in Grade 10 has been fixed, so this needs elaborated communication. Professors think it is reasonable, high school teachers are glad to see it succeed, but junior high school teachers feel it needs to be discussed further. (Male, professor of mathematics in higher education)

- Mathematics teachers are not able to teach things in context because teaching 'pure mathematics' can show teachers' authority. For example, mathematics teachers do not like to teach 'interval estimation'. They feel better if teachers of the other school subjects can teach it because it [interval estimation] is not mathematics. … The courses in the mathematics department only teach advanced mathematics, never teaching school mathematics. (Female, professor of mathematics and mathematics education in higher education)

Professors appear to have a positive view of and assume easy solutions to the (incoherent) curriculum for students. Even if incoherence can be a problem, it can be resolved by schools.

- Physics teachers can teach mathematics, so there will be trigonometric functions based on both mathematics teachers' perspectives and physics teachers' perspectives. Such diverse perspectives will benefit our students. … The general program of the national curriculum allows schools to change the schedule of teaching contents predetermined by the national curriculum (Female, professor of mathematics and mathematics education in higher education)

- If student prior knowledge of mathematics is not enough for learning physics, then a 'linking course' in the summer holiday may remedy the missing part in the curriculum. (Male, professor of vocational education in higher education)

Teachers feel the fixed curriculum, but professors do not. The gap may be resolved by principals. As such, two high school principals were interviewed.

- We are a small, country school. Most students have low socio-economic status, without money to go to cram school. Teachers of different subjects, such as mathematics and physics, can communicate to change the teaching schedule and contents. We also have summer camps for each subject, with one week for mathematics and one week for physics, to give students more teaching. (Female, principal of a country high school, north Taiwan.)

- The national curriculum can be changed, but the publishers have already published the textbooks, which are normally designed by professors and teachers. Change will increase the textbook publishers' costs, so they won't agree. Even if we have summer courses, teachers have to follow the schedule of the national curriculum and cannot teach new [next semester] content. Perhaps mathematics and physics can communicate and change schedules and content, but I have never heard of this. … Mathematics teachers won't feel they need to do this [for physics]. Perhaps some physics teachers may teach some mathematics, but this is their personal choice. (Male, principal of city high school, middle Taiwan.)

Fixed curriculum is still a limitation especially for city schools, though less for country schools. City schools have to follow the national curriculum and educational policy, no 'new and linking courses' even in summer, which is taken for granted by professors.

Issues at the student-received curriculum level

At the student curriculum level, the issue is diverse (cognitive) development with partial concern for educational inequality. The general practice is that students tend to feel frustrated in solving physics problems using mathematics skills learned through rote memorization in public schools. High-achieving and wealthy students have the advantage of support from private schooling and have relatively fewer negative influences as a result of the incoherent curriculum than non-high-achieving and poor students.

Student perception of the student curriculum

The incoherent curriculum has failed science students, especially for non-high-achieving students completely taught by the public school system.

- My physics teacher only taught basic vectors. We could not learn fully. The teacher was afraid to give us related problems. … This means that we actually did not learn the physics content. … When I did homework and saw vectors, I thought that they had not been taught completely. How could I do [my homework]? I tried to find out the answers [for the homework problems] but could not understand. I saw my classmates' homework and found no one could solve [the homework problems], either. So, I was not alone, and we were all just allowed to die together! (Male, community school, south Taiwan, id sk03)

- We learn physics vectors first and learn mathematics vectors later. When we return to calculate the previous physics using vectors, we feel that they cannot be linked together. … I asked my older brother and mathematics teachers about vectors because the physics textbook did not explain vectors clearly. … Some classmates felt they could understand because cram schools especially taught them. The students in our class asked mathematics teachers to teach vectors. The mathematics teacher told us in class that they had to teach too much content, so if we had problems, we could ask them in private. (Female, high-achieving community school, east Taiwan, id sa09)

- Without trigonometry is like dropping a tool. You have to think for a while before you use trigonometric function. … One of my classmates did not go to cram school. I remember that she often went to the physics teacher to ask questions about concepts like 'sine'. (Female, high-achieving school, north Taiwan, id ss19)

- My school always teaches very difficult sciences. …Sure, I could not understand. If I go to cram school, cram school will teach it [physics and related mathematics] first, and I'll understand. … Anyway, physics will not test the contents too much [because the related mathematics is not well taught]. I just let it go, and nothing will happen. I'll understand when mathematics teaches it. I am not the kind of student that actively asks teachers about problems. (Male, high-achieving school, north Taiwan, id sy02)

Curriculum designer perception of student curriculum

As stated in the national curriculum, curriculum designers place more emphasis on their academic domains than students. The partial emphasis on students focuses on cognitive development and mathematical thinking, which still closely link to professors' academic knowledge.

- [Three priorities are set in designing the mathematics curriculum.] First, the teaching contents need to prepare prior knowledge for the first-year mathematics-related courses in university, such as calculus, statistics, physical chemistry, introduction to computing, and economics. Second, the 12-year integrated curriculum sets Grade 10 as the last year of common courses for all students. The mathematics contents needs to fit all students' needs. … Third is cognitive development. … Vectors never independently existed in mathematics history. Physicists used space vector first, and mathematicians supplemented plain vectors later. Mathematics is a kind of language for physics. When physicists find the language is not enough to study natural phenomena, they create a language. For example, Newton created his language, which we call calculus today. So, it is better that physics teachers teach vectors first. A famous professor in Taiwan, who is good at both mathematics and physics, also believes that physics teachers should teach vectors first, and that physics teachers are spoiled because mathematics teachers have been teaching vectors for the past 20 to 30 years in Taiwan. Another example is earth science, which is a very recent development in science history and, therefore, more applied and complex. Earth science teaches and tests students on the 'Coriolis force' and 'fluid mechanics,' which are not included in the physics curriculum because the two topics are a very recent development in physics history. (Male, professor of mathematics in higher education)

- Currently outsiders think that mathematics courses tend to have become ‘simplified’. … [The reason for this simplification is that] we teach ‘mathematical thinking,’ not just ‘contents’. ... If we only want students to memorize, then a lot of content can be taught, but because we teach ‘mathematical thinking,’ it is impossible to teach too much content. Although some parts of mathematics topics can be taught separately, some still have to be taught in sequence. (Female, professor of mathematics and mathematics education in higher education)

Teacher perception of the student curriculum

From teachers’ perspectives, for students, mathematics [teachers] become useless for physics-related mathematics, as the incoherent curriculum forces physics teachers into teaching mathematics fully in detail instead of just using mathematics.

- Can I say that I think that students have good responses to my teaching [mathematics]? Sometimes they tell me, ‘Teacher, you could be a mathematics teacher’ . … For example, when we teach the projection of light, a physics problem has given you sinΘ, and sinΘ is 1/n. Therefore, you have to know cos Θ is the root of $(1-1/n^2)$. If I need to use mathematics, I will teach students repeatedly because, in my past experience, students normally have problems with mathematics. … Given the new incoherent curriculum, I'll have to spend much more time in mathematics. Why don't the professors who design the mathematics and physics curricula make more horizontal connections? They give teachers and students who want to learn so much trouble. Mathematics will teach it fully later, but we, physics teachers, have already fully taught the contents first. Isn't it a waste of time? (Female, physics teacher, age 48, teaching year 26, east Taiwan, id t11)

- When physics needs mathematics that has not been taught yet, physics will teach and use the mathematics completely. Students actually have learnt almost all the mathematics contents, but [mathematics teachers] later teach from the very beginning, such as teaching calculus. Students feel the sequence is very strange, but this is not something that we, the high school teachers, can fix. It is a big project for the Ministry of Education. I don't know how to deal with it. (Male, mathematics teacher, age 40, teaching year 10, north Taiwan, id t06)

Discussion

National curriculum: An inevitable incoherence in the national curriculum between different science subjects

An incoherent curriculum may be inevitable because of the content differences and generation gaps between older and younger sciences. The incoherent curriculum issue will lead to occasional problems if we ignore the fact that a specific science tends to be the basis for another, as in mathematics for physics, chemistry for biology, and physics for earth science.

A professor-dominated curriculum increases the barriers to implementing a coherent curriculum because research-based knowledge is often incoherent, scattered, and sometimes equivocal (Niemi, 2008). The specific professors assigned to develop the curriculum at a time, though well informed and engaged in related educational research, determine the contents that students learn for the next ten years in Taiwan. The results of this study reveal that the mathematics curriculum aims to increase depth and reduce breadth in order to teach mathematical thinking (Chiu & Whitebread, 2011). The physics curriculum aims to increase the breadth of new physics development and keep the original depth without increasing the time required to teach it (cf., Murdock, 2008; Schwartz, Sadler, Sonnert, & Tai, 2009). The trend of larger gaps between different academic disciplines in higher education inevitably increases the possibility of incoherence in the contents and sequences between difference school sciences in the national curriculum. The traditional curriculum development flow (Figure 1) further implies growing negative impacts of the professor-determined national curriculum on the teacher and student curriculum.

Teacher curriculum: Societal, trans-literal, and technological capacities for freedom to teach for students

Societal capacity. Public school teachers tend to be the most traditional Confucians in Taiwanese society. They generally obey the order of the Ministry of Education and give no voice to the stress from the society. The societal barriers against a coherent curriculum in school need to be acknowledged, faced, and overcome by a flexible curriculum with respect for schoolteachers. Cram schools, private educational organizations (including private schools), textbook publishers, and parents have played the ‘democracy’ game in education. The private educational sectors appear to force the public schools toward a fixed, powerless, and ineffective system of teaching students. Can public school teachers work together to fight for their students and their educational idealization and fight against the Ministry of Education and the private sectors? Due to this Confucian cultural influence, the answer tends to be 'no'. As shown in this study, there is little hope of changing anything at the national and teacher curriculum levels.

Trans-literal capacity. Physics teachers will have to teach mathematics (e.g., trigonometry and vectors) for physics in implementing an incoherent curriculum. A similar situation occurs with earth science: Earth science teachers need to teach about the 'Coriolis force' and 'fluid mechanics' if this content is included in the national curriculum and university entrance examinations. Similar situations also occur in higher education. For example, social sciences departments normally teach related statistics for their academic disciplines, such as educational and psychological statistics, structural equation modeling, and item response theory being taught in educational psychology departments, without reliable support from statistics or mathematics departments. From this standpoint, high school teachers need to be trans-literate in order to teach their own subjects well.

Technological capacity. Teacher autonomy with institutional collaboration to create open educational resources with technology may help increase trans-literacy and reduce educational inequality, as in MOOCs, Khan Academy, and the teacher education in sub Saharan Africa program (Murphy & Wolfenden, 2012). For example, a physics teacher, with partial support from a mathematics teacher, was invited by this present study to create a set of teaching programs on 'mathematics for physics'. The teaching lectures and presentations have been shared on YouTube (https://www.youtube.com/watch?v=XiPPGhRRhTE) and SlideShare (http://www.slideshare.net/MeiShiuChiu/01-16379816). This teaching program may supplement the limited time allotted for teaching trigonometry and vectors in the first semester of the Grade 11 physics curriculum in Taiwan.

Student curriculum: Increase in science educational inequality due to the incoherent science curricula

Who wins or loses in the incoherent curriculum battle between mathematics and physics? Mathematics curriculum and related pedagogical changes are likely to influence student science learning in both cognitive and affective aspects (Lin, Tan, & Tsai, 2013). This study shows that science students generally have negative affective responses to the incoherent curriculum due to insufficient mathematics skills to solve physics problems. The most significant losers appear to be non-high-achieving and low-income science students but cannot afford private and cram schooling. Some of these students may abandon science courses and careers because of the incoherent curriculum in the public school system. Then, rigorous science education and formal science careers will be reserved for high-achieving or high-income students in Taiwan.

This will be a tragedy for science education in terms of educational equality.

At the professor and schoolteacher level, mathematics wins and physics loses at first glance. Mathematics can be ‘independent’ and self-contained, while physics is highly dependent on mathematics and cannot survive on its own. This, however, may be an illusion. If physics teachers are fully given the authority and time to teach mathematics, then science students will need less mathematics courses and teachers than before. The curriculum design in the mathematics and physics departments of higher education reveals an unequal trans-literacy: Mathematics departments do not teach physics, but physics departments have many mathematics courses, by which physics can be ‘independent’. Should mathematics be the mother of sciences in high school? Or should mathematics not spoil physics?

Perhaps the right choice in designing the science curriculum is to center on students’ diverse cognitive, affective, and socio-economic developments. There are old and young sciences in terms of science history. The science contents, however, are sequenced in the national high school curriculum mainly based on the history of each academic discipline. Curriculum developers fail to notice the fact that there are diverse subjects co-existing in school and that students learn all these subjects at the same time. Mirroring science history development to student cognitive development appears to be a quick, convenient, and logical measure for scientists who design the curriculum but appears to be problematic for learners, as shown by students negative responses to the incoherent curriculum in this study.

Two likely solutions to the incoherent curriculum between different science subjects

Solution 1: Self-contained curriculum within each domain of science

One single concept may be reasoned, understood, and represented by different routes or subjects. Multiple representations may deepen student knowledge and cultivate student capacity for flexible thinking (Triantafillou, Spiliotopoulou, & Potari, 2013). This notion was also discussed by the mathematics educator interviewed in this study.

The acknowledgement of the benefit to students by learning mathematics via different routes suggests that physics teachers need to assume the responsibility for teaching related mathematics skills and concepts in physics classrooms. Physics textbook designs and teacher training courses may need to incorporate the ‘mathematics for physics’ to increase physics teachers’ confidence and capacity for teaching related mathematics. Similar situations can be inferred to other sciences, such as earth science.

Solution 2: A renewed curriculum development process based on rational democracy

Professors (scientists) and schoolteachers need to acknowledge their only partial knowledge and understanding of each other’s roles. Their understanding of other domains is also weak. They also do not have full knowledge of student development and learning. The acknowledgement of these weaknesses may promote collaboration between professors and teachers from different domains for the sake of improving students’ educations (Figure 2). Deliberate effort in evidence- and practice-based educational research needs to be undertaken to identify the missing knowledge of the barriers between professors, between teachers, and between professors and teachers within and across domains.

<Insert Figure 2 around here.>

References

Angell, C., Guttersrud, Ø., Henriksen, E. K., & Isnes, A. (2004). Physics: Frightful, but fun. Pupils' and teachers' views of physics and physics teaching. *Science Education, 88*, 683-706.

Askew, M., Venkat, H., & Mathews, C. (2012). Coherence and consistency in South African primary mathematics lessons. In T. Y. Tso (Ed.), *Proceedings of the 36th Conference of the International Group for the Psychology of Mathematics Education, 2*, 27-34. Taipei, Taiwan: PME.

Burny, E., Valcke, M., Desoete, A., & Van Luit, J. E. H. (2013). Curriculum sequencing and the acquisition of clock-reading skills among Chinese and Flemish children. *International Journal of Science and Mathematics Education, 11*, 761-785.

Burny, E., Valcke, M., Desoete, A., & Van Luit, J. E. H. (2013). Curriculum sequencing and the acquisition of clock-reading skills among Chinese and Flemish children. *International Journal of Science and Mathematics Education, 11*, 761-785.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed.) (pp. 509-535). Thousand Oaks, CA: Sage.

Chiu, M.-S., & Whitebread, D. (2011). Taiwanese teachers’ implementation of a new ‘constructivist mathematics curriculum’: How cognitive and affective issues are addressed. *International Journal of Educational Development, 31*, 196-206.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology, 13*(1), 3-21.

Deng, Z. (2007). Knowing the subject matter of a secondary‐school science subject. *Journal of Curriculum Studies, 39*, 503-535.

Geraedts, C., Boersma, K. T., & Eijkelhof, H. M. (2006). Towards coherent science and technology education. *Journal of Curriculum Studies, 38*, 307-325.

Huang, T. (2012). Agents’ social imagination: The ‘invisible’ hand of neoliberalism in Taiwan's curriculum reform. *International Journal of Educational Development, 32*, 39-45.

International Association for the Evaluation of Educational Achievement. (2005). *TIMSS 2003 user guide for the international database.* Chestnut Hill, MA: TIMSS & PIRLS International Study Centre.

Jablonka, E., Wagner, D., & Walshaw, M. (2013). Theories for studying social, political and cultural dimensions of mathematics education. In M. A. (Ken) Clements et al. (Eds.), *Third International Handbook of Mathematics Education Third International Handbook of Mathematics Education*, 41-67. New York: Springer.

Lin, T.-J., Tan, A. L., & Tsai, C.-C. (2013). A cross-cultural comparison of Singaporean and Taiwanese eighth graders' science learning self-efficacy from a multi-dimensional perspective. *International Journal of Science Education, 35*, 1083-1109.

Lonning, R. A., & DeFranco, T. C. (2010). Integration of science and mathematics: A theoretical model. *School Science and Mathematics, 97*, 212-215.

Marton, F. (1981). Phenomenography: Describing conceptions of the world around us. *Instructional Science, 10*, 177-200.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Murdock, J. (2008). Comparison of curricular breadth, depth, and recurrence and physics achievement of TIMSS population 3 countries. *International Journal of Science Education, 30*, 1135-1157.

Murphy, P., & Wolfenden, F. (2012). Developing a pedagogy of mutuality in a capability approach–Teachers’ experiences of using the open educational resources (OER) of the teacher education in sub-Saharan Africa (TESSA) program. *International Journal of Educational Development, 33,* 263-271.

Niemi, H. (2008). Advancing research into and during teacher education. In B. Hudso & P. Zgaga (Eds.), *Teacher education policy in Europe: A voice of higher* *education institutions* (pp. 183-208). Umeå, Sweden: University of Umeå, Faculty of Teacher Education.

Park, E. J., & Choi, K. (2013). Analysis of student understanding of science concepts including mathematical representations: ph values and the relative differences of ph values. *International Journal of Science and Mathematics Education, 11*, 683-706.

Schwartz, M. S., Sadler, P. M., Sonnert, G., & Tai, R. H. (2009). Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. *Science Education, 93*, 798-826.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

Strauss, A., & Corbin, J. (1998). Grounded theory methodology: An overview. In N. K. Denzin & Y. S. Lincoln (Eds.), *Strategies of qualitative inquiry* (pp. 158-183). Thousand Oaks, CA: Sage.

Szendrei, J. (2007). When the going gets tough, the tough gets going problem solving in Hungary, 1970–2007: Research and theory, practice and politics. *ZDM Mathematics Education, 39*(5), 443-458.

Triantafillou, C., Spiliotopoulou, V., & Potari, D. (2013). Periodicity in textbooks: Reasoning and visual representations. In Lindmeier, A. M. & Heinze, A. (Eds.). *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education, 4*, 297-304. Kiel, Germany: PME.

Tsai, C. C., & Kuo, P. C. (2008). Cram school students' conceptions of learning and learning science in Taiwan. *International Journal of Science Education,30*, 353-375.

Table 1

Content of Mathematics and Physics Courses in the 1st Semester of Grade 11 Science according to the 2010 Curriculum in Taiwan

	Phase 1	Phase 2	Phase 3
Mathematics	Half knowledge of trigonometry[1]	Straight lines and circles	Vectors
Physics	Linear motion Projectile motion	Static equilibrium; Newton's laws	Circular motion; Simple harmonic motion
(mathematics for physics)	(Full knowledge of trigonometry; Partial knowledge of vectors)	(More knowledge of vectors)	(Full knowledge of trigonometry and vectors)

Note 1. The other half knowledge of trigonometry is taught in Grade 12.

Table 2

Responses of Professors, Mathematics Teachers, Physics Teachers, and Science Students to the Incoherent Curriculum Between Mathematics and Physics at the National, Teacher and Student Levels.

	National curriculum	Teacher curriculum	Student curriculum
Professors	1. Mathematics has its own identity and system, while other subjects see mathematics as a language or tool. 2. Professors determine teaching contents with concern for educational policy.	1. Mathematics teachers do not have sufficient ability to teach mathematics in context. 2. Pure mathematics and mathematical thinking are the focus of mathematics teaching in school.	1. Student cognitive development is similar to mathematics history. 2. Students will benefit from multiple perspectives toward the same mathematics concepts and skills.
Mathematics teachers	1. Mathematics and physics have a strong relationship. 2. Physics justifies difficult mathematics content. 3. Physics curriculum can change to fit mathematics curriculum.	1. Mathematics and physics teaching have little relation. 2. The problem of incoherence should be solved by physics teachers or the national curriculum.	1. Science students need mathematics courses. 2. Students can learn mathematics well from physics teachers.
Physics teachers	1. Mathematics and physics have a very strong relationship. 2. Physics has its unchanged order in history and knowledge development. 3. The physics curriculum increases new content.	1. Physics teachers teach related mathematics in detail. 2. Mathematics teachers should help but cannot because of the fixed curriculum and cram school.	1. Students admire physics teachers' mathematics teaching. 2. Time is wasted in teaching the same contents in mathematics and physics.
Science students	1. Physics learning needs key mathematics knowledge and skills to be taught well one term earlier. 2. Students have negative responses to the incoherent curriculum.	1. Most physics teachers teach some physics-related mathematics. 2. Cram and private schooling compensate for the incoherent curriculum.	1. Students' physics abilities decrease when solving physics problems using rote-learned mathematics. 2. The reduced physics ability is salient for non-high-achieving, low-private-support students.

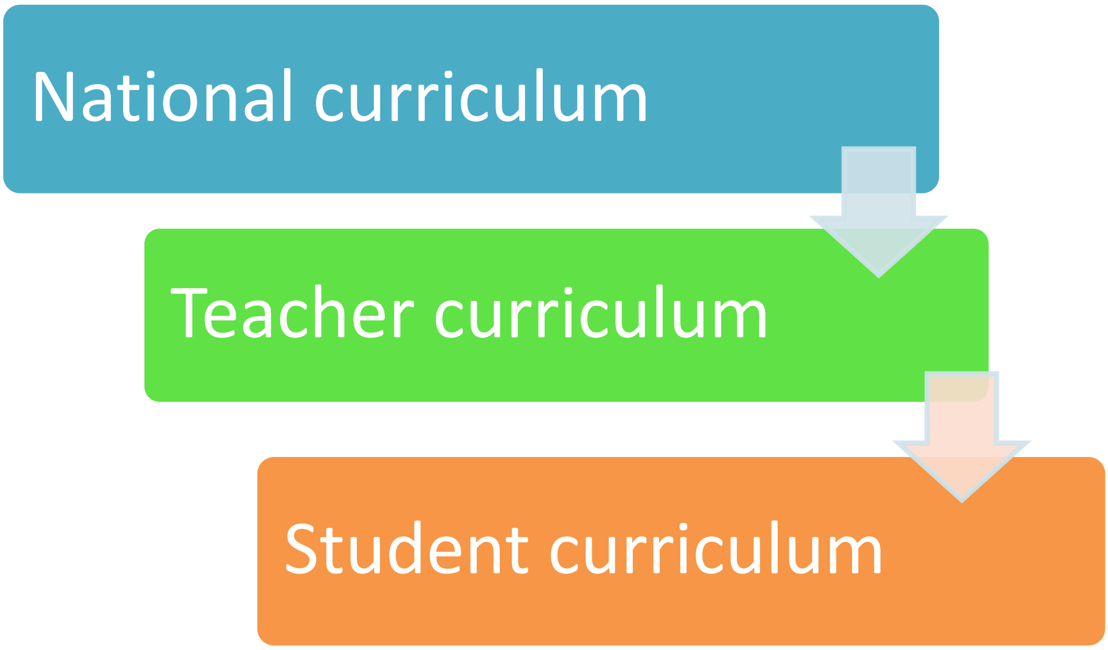

Figure 1. The traditional curriculum development process based on 'hierarchical democracy'.

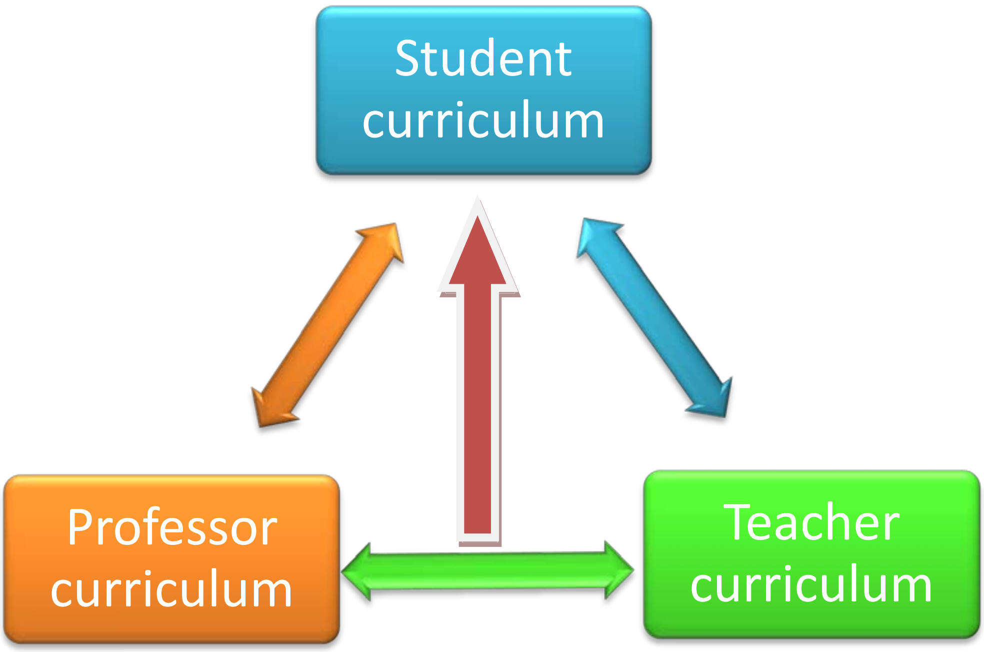

Figure 2. The renewed curriculum development process based on 'rational democracy'. Equitable professor and teacher curricula are at the bottom to support excellent student curriculum.

國科會補助專題研究計畫出席國際學術會議心得報告

日期： 102 年 9 月 14 日

計畫編號	NSC 101-2511-S-004 -001		
計畫名稱	數學與其他知識領域的關係：課程問題發現與解決		
出國人員姓名	邱美秀	服務機構及職稱	國立政治大學教育學系 教授
會議時間	2013 年 7 月 28 日至 8 月 2 日	會議地點	Kiel, Germany (德國)
會議名稱	(中文) 國際數學教育心理學組織第 37 屆會議 (英文) the *37th Conference of the International Group for the Psychology of Mathematics Education (PME37)*		
發表論文題目	(中文)數學與物理間未協調之課程實施議題 (英文) Issues in implementing an incoherent curriculum between mathematics and physics		

一、參加會議經過

7 月 28-8 月 2 日：註冊、參加會議安排的學術與交流活動、發表論文。

二、與會心得

1、此次 The 37th Conference of the International Group for the Psychology of Mathematics Education (此組織簡稱 IGPME，此會議簡稱 PME37)，依會議手冊大致計算，約有 600 篇左右論文發表，出席人數眾多，發表論文者大多為數學背景再轉數學教育之大學學者及研究生，少數為其他教育背景，例如教育心理學、教育社會學等。PME 的出席者來自世界各國，臺灣學者有多人參加，上一屆的 IGPME 主席為臺師大的林教授、去年 PME36 在臺灣舉辦，足見臺灣在此組織上有佳的參與力、影響力。

2、此會議因已第 37 屆，有優久的歷史，其學術活動多元，包括 keynote speech、research report、short oral、poster、discussion group、research forum，讓與會者能有不同的互動型式，而能有利於建立研究社群。其次，此會議也安排一些 informal 的互動交流活動，包括 reception、coffee break、lunch break、dinner、organizing and new-comer meetings 等。活動多元而充分，能加深與加廣與會者的互動層次。

3、此次，計發表 2 篇論文。其中 1 篇為獨立發表有關數學與物理課綱關聯的議題，與會的瑞典與美國學者，給我一些很有趣的思考點、他國的文化經驗、寶貴建議與想法，覺有所收穫。另 1 篇為與臺灣另一位教授共同發表有關數學創造力的論文，與會學者問及有關數學創造力與一般創造力、數學成就、教師評量關係的議題，有助於後續資料分析與論文寫作。同場次學者論文的發表，在研究方法、文獻、思考上，也提供寶貴的新穎思考點，例如統計的先備知識研究，即結合數學與教心二領域的學者與研究方法，此場次會後，與研究者進一步討論，了解到其跨領域結合的研究方式。

4、與 poster 發表者的互動，往往能有很深入的討論。此次，有一德國博士生的研究，比較德國和臺灣的數學教師，其研究法為對國際資料庫進行二次分析。她將於今年來臺，我們已連絡，預計她將到我的相關課堂上分享其論文，並與學生一起討論相關議題。

三、發表論文摘要

Chiu, M.-S. (2013). Issues in implementing an incoherent curriculum between mathematics and physics. In Lindmeier, A. M. & Heinze, A. (Eds.). *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education, 5,* 42. Kiel, Germany: PME.

THEORIES, CONTEXTS, AND METHODS

Coherent curriculum design is required between mathematics and physics given that the two domains are closely interwoven and when mathematics curriculum calls for external connections with life as mediating means (Askew, Venkat, & Mathews, 2012; Lonning & DeFranco, 2010). Incoherence between mathematics and physics saliently occurs in the high-school curriculum of 2010 in Taiwan. Grade-11 science students study motion and dynamics in physics without any prior learning experiences of trigonometry and trigonometric function in mathematics. Qualitative research methods were used to investigate the perspectives and actions of 51 science students, 22 mathematics and physics teachers, and 3 curriculum developers/professors, with an aim to identify the issues in the implementation of the curriculum.

RESULTS AND DISCUSSION

In the national intended curriculum level, the issue is domain boundaries: Mathematics emphasizes abstraction, procedures, and theorems, while physics emphasizes scientific advances, concepts, and unified truth. In the teacher implemented curriculum level, the issue is fix curriculum: Mathematics teachers feel relaxation and independence given fewer, easier, and self-contained contents, while physics teachers feel anxiety and helplessness given wider contents and insufficient mathematics ‘tools’ for physics. In the student received curriculum level, the issue is diverse cognitive developments: Students learned the quickly-taught new mathematics by physics teachers, with a negative impression of physics teaching in school. The findings suggest that the curriculum development process based on ‘hierarchical democracy’ needs to be transformed into a renewed framework, with equitable expert and teacher curricula at the bottom to support excellent student curriculum based on ‘rational democracy’.

References

Askew, M., Venkat, H., & Mathews, C. (2012). Coherence and consistency in South African primary mathematics lessons. In T. Y. Tso (Ed.), *Proceedings of the 36th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 27-34). Taipei, Taiwan: PME.

Lonning, R. A., & DeFranco, T. C. (2010). Integration of science and mathematics: A theoretical model. *School Science and Mathematics, 97*(4), 212-215.

四、建議

1、長期的研究社群經營，有賴人所設立的不斷學習改進的機制：這次會議於 reception 時，即謙卑的表示：歡迎與會者隨時提供寶貴建議；於 discussion group 中，也發現這樣的「謙卑」，group leader 於最後，直接計數未來會議仍會參與此主題之 discussion group 的人數，並說明「參與者的未來參加意願」為此 discussion group 是否能持續的最重要因素。也許，有系統地於學術活動中加入「評估未來意向」的機制，是一個組織可長可久、與時併進的重要策略。

2、正式、非正式、學術、社交、長期、短期的活動交錯進行，有助增加參與者的投入程度：學術研究有其嚴肅性，需要很大的「知能投入」；但，人的「專注力」是有限的，過度集中與長久的「知能」活動，易使人產生疲累感。此會議的活動設計，單日內，交錯出現不同種類的活動，能有助支撐團體動力、建立社會網路、持續參與者參加各式活動的活力。

五、攜回資料名稱及內容

1、會議手冊(紙本)，含會議相關資訊、議程(含時間安排、所有與會者名單、論文名稱…等)。
2、會議論文集(電子檔)，含此會議的所有論文內容。

六、 其他：論文發表之大會證明文件

PME 37
Kiel · Germany

IPN · Olshausenstr. 62 · 24098 Kiel · Germany
Chiu, Mei-Shiu
National Chengchi University
Department of Education
64, Zhinan Rd. Sec. 2
11605 Taipei
Taiwan, R.O.C.

Chair of PME 37
July 28, 2013

To Whom It May Concern

This is to confirm that Mei-Shiu Chiu attended the 37th Conference of the International Group for the Psychology of Mathematics Education held in Kiel (Germany), July 28 – August 2, 2013.

Mei-Shiu Chiu has presented the following paper:

Title: ISSUES IN IMPLEMENTING AN INCOHERENT CURRICULUM BETWEEN MATHEMATICS AND PHYSICS
Type of Submission: Short Oral Communication

We thank Mei-Shiu Chiu for the contribution to the scientific program of PME 37.

Prof. Dr. Aiso Heinze
(PME 37 Conference Chair)

國科會補助計畫衍生研發成果推廣資料表

日期:2013/09/12

國科會補助計畫	計畫名稱: 數學與其他知識領域的關係：課程問題發現與解決	
	計畫主持人: 邱美秀	
	計畫編號: 101-2511-S-004-001-	學門領域: 數學教育

無研發成果推廣資料

101 年度專題研究計畫研究成果彙整表

計畫主持人：邱美秀	計畫編號：101-2511-S-004-001-
計畫名稱：數學與其他知識領域的關係：課程問題發現與解決	

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數(含實際已達成數)	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		邱美秀(2012)。High-school student perceptions of relationships between mathematics and the other domains。論文發表於台灣心理學會第 51 屆年會，亞洲大學，台中市，2012 年 10 月 13-14 日。
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	1	1	100%	人次	擔任計畫兼任助理。
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	2	2	100%		Chiu, M.-S. (2013). Issues in implementing an incoherent curriculum between mathematics and physics. In Lindmeier, A. M. & Heinze, A. (Eds.). Proceedings of the 37th Conference of the International Group for the

							Germany: PME. Paper presented at the 37th Conference of the International Group for the Psychology of Mathematics Education, Kiel University, Kiel, Germany, 28 July - 2 August.（NSC 101-2511-S-004 -001） 協助其他數教計畫，進行資料分析與論文撰寫工作。 Leu, Y.-C., & Chiu, M.-S. (2013). Development of the Creative Disposition toward Mathematics Scale. In Lindmeier, A. M. & Heinze, A. (Eds.). Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education, 5, 105. Kiel, Germany: PME. Kiel, Germany: PME. Paper presented at the 37th Conference of the International Group for the Psychology of Mathematics Education, Kiel University, Kiel, Germany, 28 July - 2 August. (NSC 99-2511-S-152-003-MY3; NSC 101-2511-S-004 -001)
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	1	「高中物理數學」課程，主要內容包括(一)三角函數簡介(角度與直角三角形)、長度的投影、三角函數的特殊關係、和角、差角公式、倍角、半角、三倍角公式、正餘弦定理、小角度近似；(二) 向量簡介、向量加減法、向量乘法與內積
	電腦及網路系統或工具	1	「高中物理數學」課程之講述教學共 12 講，以 Power Cam 製作，分享於 YouTube。至 YouTube，打關鍵字「高中物理數學」，即可免費觀看、取得。第 1 講連結為：高中物理數學_01 簡介三角函數 1：角度 https://www.youtube.com/watch?v=XiPPGhRRhTE
	教材	1	「高中物理數學」教學用教材 ppt 共 10 則，分享於 Slideshare。至 Slideshare，打關鍵字「高中物理數學」，即可免費觀看、取得。第 1 則連結為：高中物理數學 01 簡介三角函數 http://www.slideshare.net/MeiShiuChiu/01-16379816
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	1413	「高中物理數學」課程講述教學、ppt，於 youtube 和 slideshare 分享，20130914 合計觀看人數。

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　　□實驗失敗

　　□因故實驗中斷

　　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 □未發表之文稿 ■撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

研究成果已發表在 3 個學術研討會，由參與研討會所得之與會學者建議，將持續修改與加強論文內容，投稿至學術期刊。

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

此計畫探討「數學與其他知識領域關係」的議題，是數學教育界較少探索的主題，但是，卻能以第一手的實證資料，來重新解讀數學對世界知識、文化、社會、課綱的價值與定位。也希望本計畫針對議題的探討，而發掘出教育界難解、待解的問題，能為未來更佳的教育設計奠立基礎。