J. Korean Soc. Math. Educ., Ser. D, Res. Math. Educ.
Vol. 22, No. 3, 153-174, September, 2019
http://doi.org/10.7468/jksmed.2019.22.3.153

Alignment between National College Entrance Examinations and Mathematics Curriculum Standards: A Comparative Analysis

Dae S. Hong (Professor) [1*], Yejun Bae (Gradate Student)[2], Yu-Fen Wu (Graduate Student)[3]

[1]University of Iowa, dae – hong@uiowa.edu
[2] University of Iowa, yejun-bae@uiowa.edu
[3] University of Iowa, yu-fen-wu@uiowa.edu

(Received September 3, 2019; Accepted September 19, 2019)

Measuring alignment of various educational components is an important issue in educational research because with aligned educational system, we can have clear expectations about what to teach and assess. In this study, we examined the alignment between mathematics curriculum standards and college entrance examinations from Korea and China. The results indicate that curriculum standards and high stakes assessments from both countries are not well aligned to each other. Their Surveys of Enacted Curriculum (SEC) indices were lower than what previous studies have found and the critical values (Fulmer, 2011; Liu & Fulmer, 2008; Liu et al., 2009). There are several topics that are not assessed in both countries' national assessments. Also, discrepancies between the most frequently covered topics in the curriculum standards and the most frequently assessed mathematical topics in the national assessments caused topic level misalignment. We also found misalignment in cognitive level. Both national assessments included more perform procedures and demonstrate understanding items than their respective curriculum standards. Thus, previous findings about the inclusion of more items with higher cognitive demand in assessments is only partially true for either country. With these results, it is difficult to say that whether mathematical topics in the curriculum standards appropriately represent and support students to do well on the CSAT and the NCEE or that the mathematical items in the CSAT and the NCEE validly assess students' level of mathematical understanding.

Keywords: Alignment, College Entrance Examinations, Curriculum Standards
ZDM classification: D60.
2000 Mathematics Subject Classification: 97C40

I. INTRODUCTION

Many educational researchers have examined alignment between standards, curriculum materials, and assessments in education (Herman & Webb, 2007; Liu & Fulmer, 2008; Liu

* Corresponding Author: dae-hong@uiowa.edu

et al., 2009; Polikoff, Porter, & Smithson, 2011). When content standards and high-stakes standardized tests are aligned, instruction is expected to align with content standards, as well as other components of the educational system, such as professional development (Herman & Webb, 2007). Measuring alignment between curricula expectations and assessments strengthens an educational system in important ways (Webb, 1997a). When there is not a strong alignment between standards and assessments, it is possible that teachers can simply ignore desired standards and, instead, teach only what is included in assessments (Herman, Webb, & Zuniga, 2007). Moreover, if what is tested does not reflect curricular expectations for student performance, the test results cannot provide valid data about students' or schools' progress relative to those expectations. It would be difficult to take action to improve students' performances based on such results (Herman & Webb, 2007). However, if expectations and assessments are well aligned, teachers can design their lessons and instructional practices accordingly. Such aligned educational systems are more efficient and effective (Webb, 1997a).

In mathematics education, results from international comparative studies such as the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) consistently show that American students do not perform well compared to their international counterparts (Mullis, Martin, Foy, & Arora, 2012; Mullis, Martin, Foy, & Hooper, 2016; Organisation for Economic Cooperation and Development [OECD], 2015). To understand how students in other countries learn mathematics, educational researchers have examined class practices (Cai, 2005), structure of curriculum standards (Schmidt, Wang, & McKnight, 2005) and high – stakes examinations (Hong, 2011), and textbooks (Hong & Choi, 2014, 2018; Hong, Choi, Runnalls, & Hwang, 2018; Son & Hu, 2016). These studies present valuable results about mathematics education in other countries and help us understand possible contributing factors in students' achievement differences.

Another way to understand mathematics education in other countries is to measure alignment between high-stakes examinations and mathematics content standards. It is found that high–stakes assessments drive class instruction and impact curricula content (Au, 2007). Measuring alignment between curriculum standards and assessments has been done several times in science education (Liang & Yuan, 2008; Liu & Fulmer, 2008; Liu et al., 2009), and American state mathematics curriculum standards and assessments were previously compared (Polikoff et al., 2011). However, mathematics curriculum standards and high–stakes assessments in East Asian countries have not been compared often. In this study, we will measure alignment between mathematics items in high-stakes assessments (e.g. college entrance examinations) and mathematics curriculum standards in international assessments from two top performing countries ─ Korea and China. Both have national content standards and have administered standardized tests for a much longer time than the

United States (Liu, 1996) and also, a similar structure in mathematics curriculum standards in East Asian countries can be a contributing factor in understanding international assessments (Schmidt et al., 2005) so examining their alignment may help us develop a further understanding of mathematics education of Korea and China with several implications to curriculum developers, assessment developers, policy makers, and educators because examining alignment may lead to refinement of curriculum standards, textbooks, examinations, and classroom instruction (Ma et al., 2013). If high – stakes assessments and curriculum standards are well aligned, teachers and students can have clear expectations of what to teach and learn, which can be interpreted as one of possible reasons for their high performances. Here are the research questions that we will attempt to answer.

1) How do the curriculum standards and the assessments agree in terms of cognitive level?
2) How do the curriculum standards and the assessments agree in terms of content area (e.g. mathematical topics)?
3) What are the differences and similarities between the curriculum standards and the assessments in Korea and China?

II. LITERATURE REVIEW

1. MEANING OF ALIGNMENT

Educational researchers recognize the alignment between an educational assessment and a set of content standards in a subject as evidence of the assessment's validity, or an accurate interpretation of the assessment results (Resnick, Rothman, Slattery, & Vranek, 2004; Webb, 1997b). Alignment can be defined in several ways. At the classroom level, alignment is agreement between a teacher's objectives, activities, and assessments (Tyler, 1949). More generally, alignment can be defined as the degree to which the components of an education system, content curriculum standards, assessments, and instruction are in agreement to properly assess and evaluate students (Resnick et al., 2004; Webb, 1997b). In measuring alignment of various components of an educational system, educational researchers often examine the alignment between expectations (e.g. curriculum standards) and assessments to understand the validity of the results of those assessments (Bhola, Impara, & Buckendahl, 2003; Liu & Fulmer, 2008; Polikoff et al., 2011; Webb, 1997a). Furthermore, to measure alignment among educational components, educational researchers examine the amount of topic overlap between content standards, textbooks, and classroom coverage (Schmidt & Prawat, 2006). In the United States, when the

Common Core State Standards of Mathematics (CCSSM) were developed, attaining alignment was also recognized because to make a difference in students' opportunities to learn important and useful mathematics with new standards (e g. CCSSM), various components of the educational system need to align with those standards (Heck, Weiss, & Pasley, 2011).

When an aligned educational system is in place, students can be assessed and demonstrate their knowledge and skills with respect to the expectations that were set up in the curriculum frameworks and teachers' lessons (Martone & Sireci, 2009). Korean and Chinese college entrance examinations both assess students to see if they are ready for college education. Both entrance examinations greatly influence and shape mathematics teaching. Thus, measuring alignment may allow us to explore questions about reasons behind Korean and Chinese students' high performances in international assessments.

Measuring alignment often includes topic level as well as cognitive level. Webb (1997a) called these range of knowledge and depth of knowledge, while others used the term "cognitive demand" (Polikoff, 2015; Polikoff et al., 2011). Topic level alignment provides a very general indication of alignment of whether both documents incorporate the same content (Webb, 2007). When examining alignment in topic levels, we can see whether certain topics are overemphasized (or over-tested) or underemphasized (or under-tested) (Polikoff et al., 2011). It is natural to think that when some topics are under-tested (or over-tested) compared to curricula expectations, validity of such assessments will be questioned.

Cognitive level alignment indicates if what is elicited from students on the assessment is as demanding cognitively as what students are expected to know and do as stated in the curriculum standards (Webb, 2007). When cognitive levels in educational components are not aligned well, students may not be assessed properly even if those components are well aligned at the topic level because of discrepancies in cognitive expectations. In this study, we measured alignment between two educational components, mathematics curriculum standards and mathematics items on national college entrance examinations.

2. PREVIOUS STUDIES

Several studies have measured alignment between assessment and curriculum standards in science (Liang & Yuan, 2008; Liu & Fulmer, 2008; Liu et al., 2009; Lu & Liu, 2012). These studies examined the alignment between Chinese, Singapore, and New York State science curriculum standards and high school exit examinations in biology (Lu & Liu, 2012), physics (Liang & Yuan, 2008) and chemistry and physics (Liu & Fulmer, 2008; Ma et al., 2013). The results from these studies showed that, in many cases, alignment between assessment and curriculum standards in science is not statistically significant, with alignment indices anywhere from .46 to .713. Alignment in cognitive level shows that assessments tend to include more cognitively demanding science tasks than curriculum standards (Liu et al., 2009; Ma et al., 2013). An interesting finding from these studies is that high alignment indices are not necessarily interpreted as a good result because of an emphasis on lower level cognitive thinking (Liu et al., 2009). The New York State Physics Regents examinations were statistically significantly aligned compared to those of Singapore and China; however, over–emphasis on lower level thinking led to lowering students' expectations in learning (Liu & Fulmer, 2008). These studies recommend that alignment studies should be conducted often so students and teachers can have expectations that curriculum standards, assessments, and instructional practices agree with each other, although there can't be a perfect alignment among them (Liu & Fulmer, 2008; Liu et al., 2009).

Alignment between states mathematics curriculum standards, textbooks, and assessments have also been measured (Polikoff, 2015; Polikoff et al., 2011; Webb, 1999). Polikoff (2015) compared three Common Core aligned elementary textbook series with CCSSM, finding all to have alignment indices with the standards of .4 or lower. A primary source of misalignment is that the textbooks systematically overemphasize procedures and memorization and underemphasize more conceptual skills relative to their emphasis in the standards. Also, each textbook has its own emphasis in terms of topic coverage (Polikoff, 2015), informing teachers about how textbooks treat elementary mathematics topics and the gaps between the standards and textbooks. These findings are useful in preparing professional development for teachers as well as in the textbook development process to fill the gaps between the standards and textbooks. Webb (1999) found that a large proportion of assessment items that was of lower cognitive demand than the material identified in the standards and assessment items failed to cover 50% or more of the content in the content standards. Furthermore, average alignment indices for state standards and assessments were below .30 in mathematics and science (Polikoff et al., 2011).

These results help to understand expectation levels for teachers and students when they develop mathematical lessons and take these standardized examinations. Knowing students' expectation levels can also be useful for teachers when planning their daily lessons, informing them about areas that are under- or over-emphasized so that they can attempt to fill the gaps between what is assessed and what is expected.

III. RESEARCH METHODLOGY

1. DATA SOURCES

Korea and China have national curriculum standards and standardized assessments. In this study, we used each of their most recent secondary mathematics curriculum standards and analyzed the three most recent national college entrance examinations from each of country (years 2015 to 2017).

Korea has a centralized educational system, so the Ministry of Education (MOE) provides guidelines to colleges and universities in their selection of students. The current College Entrance Examinations, called the College Scholastic Aptitude Test (CSAT), were developed by the MOE and adopted in February 1993. (More information about the CSAT can be found at the Korean Institute for Curriculum and Evaluation [KICE] website: http://www.kice.re.kr.). The main purpose of CSAT is to measure students' scholastic ability required for college education (Nam, 2014). As of 2018, the CSAT includes five sections: Korean, mathematics, social studies and sciences, English, and foreign languages. The mathematics section totals 100 points and students are given 100 minutes to complete the section. The mathematics portion of the CSAT has two versions: the Na examination and the Ga examination. The Na exam includes no topics more advanced than pre-calculus; it covers, for example, exponential and logarithmic functions, equations, and inequalities. The Ga exam covers the more advanced topics listed Table 1. Originally, the Ga exam was intended for science-related majors and the Na exam for liberal arts majors. Since 2005, however, students have the option of taking either the Ga or the Na exam, regardless of their area of study. This study examined the last three Ga exams. The mathematics portion includes 21 multiple choice and 9 short response items.

Mathematics curriculum standards are also developed by MOE. In Korea, newly revised curriculum guidelines were announced in 2009. There are several mathematics classes that high school students need to take and cover the content of the CSAT (Table 1). CSAT covers mathematics topics that Korean high school students learn in their second and third year of high school (Nam, 2014). In this study, we coded mathematics items from the Ga exams and curriculum standards from mathematics classes in Table 1.

Table 1. Korean mathematics classes

	High School Mathematics Class
Ga Exam	Differential and Integral Calculus II Differential and Integral Calculus 1 Probability and Statistics Geometry and Vectors Mathematics II
Na Exam	Differential and Integral Calculus 1 Probability and Statistics Mathematics II

The National College Entrance Examination (NCEE) in China consists of three sections: Chinese Literature, Mathematics, and English. Students with a natural science orientation choose to take an additional exam on physics, chemistry, and biology; students with a social science orientation take an additional exam on history, politics, and geography. The national examination is held annually over a period of two days in June. Some areas such as Beijing, Shanghai, Tianjin, Jiangsu, Zhejiang create their own examination sets. In this study, we examined the national versions for science related majors.

The mathematics portion of the NCEE is designed based on the Scheme on Senior High School's Curriculum, the General High School Math Curriculum Standard (Tu, 2018), and the Colleges and Universities Enrollment Unified National Examination Outline in Mathematics (http://www.moe.gov.cn). The mathematics portion of the NCEE totals 150 points and students are given 120 minutes to complete the section. There are four types of problems: multiple choice (12 problems, 60 points total), fill-in-the-blank (4 problems, 20 points total), must-answer problems to perform the process of problem solving (5 problems, 60 points total), and optional problems to perform the process with content based on the 10 elective topics of the fourth series in the General High School Math Curriculum Standard. For the optional problems, students may choose one to answer for 10 points. The availability of higher education in China is fairly low compared to the Western world. Consequently, the examination is highly competitive. The influence of the NCEE is tremendous in the curriculum and instruction teachers use in the classroom. There are five required modules before students take elective classes based on their future interests (Wang, Liu, Du, & Liu, 2018). These modules and classes cover the content of the NCEE, which includes plane vectors, sets and simple logic, functions, inequalities, trigonometric functions, sequences, the functions of lines and circles, the functions of conic curves, lines, planes and simple geometries, permutations, combinations and the binomial theorem, probability and statistics, limits, derivatives, and extension of the number system from real numbers to complex numbers (Tu, 2018). In this study, we examined mathematics standards from all required modules and electives for future science and mathematics students.

2. MEASURING ALIGNMENT

There are two well-known ways to measure alignment of different educational components, the Webb Alignment Tool (WAT) and Surveys of Enacted Curriculum (SEC) (Martone & Sireci, 2009; Newton & Kasten, 2013). The WAT includes more detailed analysis of alignment than the SEC while the SEC includes simpler ways to measure alignment in terms of content topics and cognitive demand (Martone & Sireci, 2009; Newton & Kasten, 2013). The Webb alignment method assumes a specific content standard and uses it as the basis for analyzing the alignment of the test, which is not applicable to international alignment comparison studies such as the present one because different countries have different content standards. We needed an alignment method that is independent from content standards and standardized tests (Liu et al., 2009). Thus, we used the SEC in this study.

3. SURVEYS OF ENACTED CURRICULUM

This study used the Surveys of Enacted Curriculum (SEC), which were employed to measure alignment between textbooks and curriculum standards and between assessments and curriculum standards (Liang & Yuan, 2008; Liu & Fulmer, 2008; Lu & Liu, 2012; Ma et al., 2013; Polikoff, 2015). The SEC provides a simple way to measure alignment using two matrices and the following formula:

$$\text{Alignment Index} = 1 - \frac{\sum_{i=1}^{n} |x_i - y_i|}{2}$$

where n is the total number of cells in the table. Here, x_i is the proportion of content in cell *i* of document *x* (e.g. topics in mathematics curriculum standards) and y_i is the proportion of content in cell *i* of document y (e.g. mathematics items in college entrance examinations, textbooks, or any other curriculum materials). Both x_i and y_i have a value between 0 and 1. If two documents are perfectly aligned, the alignment index is 1. Thus, an index closer to 1 shows better alignment between the two documents. For example, in the two frequency tables below, there are 4 common items (out of 10 total items) from the four cells, which is 40 % alignment.

Frequency Tables

0	1
4	5

3	4
2	1

Ratio Tables

.0	.1
.4	.5

.3	.4
.2	.1

$$\text{Alignment Index} = 1 - \frac{\sum_{i=1}^{n} |x_i - y_i|}{2} = 1 - \frac{1.2}{2} = .4$$

For this study, one table will provide the frequency of mathematics topics and cognitive levels of those topics in the curriculum standards and the second table will show the frequency of items in the national college entrance examinations in terms of topics and cognitive levels.

An important aspect of alignment between standards and assessments is whether both address the same content categories, which provides a very general indication of alignment (Webb, 2007). In the SEC, there are also two areas of measuring alignment ─ content and cognitive levels (Polikoff, 2015; Polikoff et al., 2011). As we described earlier, topic level allows us to see what topics were emphasized and presented in the curriculum standards as well as in the national assessments. The cognitive levels are a revised version of Bloom's taxonomy of *Memorize, Perform Procedures, Demonstrate Understanding, Conjecture, Generalize, Prove* and *Solve non-routine problems, and Make connections*. A cognitive level analysis informs us about what cognitive levels of items were expected and included in both the curriculum standards and national assessments. With both content and cognitive level analyses, we see topical alignment as well as the alignments of cognitive complexities between the curriculum standards and assessments. We can also examine whether certain mathematical topics or cognitive levels were consistently emphasized and presented over three years' time. It is beneficial when topics and various cognitive levels are presented and distributed equally in both the standards and assessments over time. These results will inform us about what students in top performing countries are expected to know and assessed on. Such results are valuable resources for teachers, test developers, and educational policy makers in the United States.

4. CODING EXAMPLES

Prior to coding each assessment item and standards statement, we need to consider the unit of analysis, which is one of the challenging parts of alignment research (Fulmer, Tanas, & Weiss, 2018). We examined each item carefully to see if we need to break assessment items into more than one unit. After carefully examining each item from CSAT and NCEE, we did not find any items that we need to break into more than one unit. For example, items in Figures 1 and 2 involved with one main mathematical topic, conic sections and differentiation respectively. For standards statements, we also examined each statement to see if each statement represents more than one mathematical idea. Again, we did not find any standards statements that contain more than one mathematical idea. For example, each of four standards statements in Figure 3 is about one mathematical topic.

Suppose that in an ellipse C with equation $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1\ (a>b>0)$, exactly three of the four points $P_1(1,1)$, $P_2(0,1)$, $P_3\left(-1,\frac{\sqrt{3}}{2}\right)$, and $P_4\left(1,\ \frac{\sqrt{3}}{2}\right)$ lie on C.

Find the equation of C. (NCEE, 2017).

Figure 1. One example from NCEE 2017.

First, at the topic level, this was coded as conic sections. In terms of cognitive level, this was coded as perform procedures. The problem can be solved by knowing what an ellipse is.

In the following figure, a circular paper is centered at O and has radius 5 cm. An equilateral triangle on the paper ABC also has center at O. The points D, E and F lie on the circle O and ΔDBC, ΔECA and ΔFAB are isosceles with bases BC, CA and AB, respectively. If the paper is cut along the dashed lines and folded along BC, CA and AB, three triangles ΔDBC, ΔECA and ΔFAB are formed, so that the points D, E and F coincide. In this way, we get a tetrahedron. When the side length of ΔABC varies, the resulting tetrahedron has greatest volume?

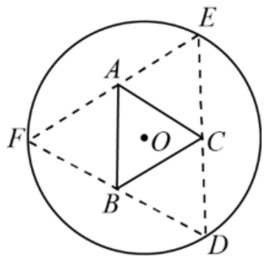

Figure 2. Another example from NCEE 2017

This item was coded as differentiation and demonstrate understanding. Finding the maximum value is obviously tied to differentiating a function. Students are also not going to be able to solve this by just finding the derivative of a function. They need to know and use properties of the equilateral triangle, 30-60-90 triangle, and the Pythagorean Theorem to express the height of the pyramid in terms of x. While they are using equilateral triangle, 30-60-90 triangle, and the Pythagorean Theorem, they need to demonstrate their understanding by using different representations and explain relationships between those concepts – characteristics of items in *Understanding* category; however, students were not asked to make conjecture (or proofs) or apply mathematics in contexts outside of mathematics - characteristics of items in *Conjecture*, and *Solve non-routine problems* categories.

- Understand the meaning of logarithmic function.
- Differentiate sine and cosine functions.
- Using the derivative of a function to solve equations or inequalities
- Being able to prove how lines and planes are related.

(Ministry of Education in Korea, 2011)

Figure 3. Sample standards statements from Korean curriculum standards (Ministry of Education in Korea, 2011)

In Figure 3, we have four sample standard statements from the Korean curriculum standards. In terms of topics, we coded these as exponential and logarithmic functions, differentiation (both second and third statements) and geometry of space. In terms of cognitive demand, these were coded as memorize, perform procedures, demonstrate understanding, and conjecture or prove.

5. RELIABILITY OF CODING

To code curriculum standards and assessment items, we first translated the NCEE items and the Chinese curriculum standards. For coding reliability, two of the three authors independently coded each curriculum standards statement and exam item (the first author was part of both processes). The initial agreement rate was 94% and 96%, respectively. In all, we coded 90 mathematical text items from the CSAT and 96 mathematical test items from the NCEE, and 96 and 204 mathematics curriculum standards statements from Korean and China respectively. Curriculum statements and test items in each assessment were classified into a cell of the identical table. We used mathematics content categories in SEC to assign each coded test item and curriculum standards statement into a cell. After all the items were coded, the total points of the items in each cell were calculated and used as the cell value. A value of 0 was entered as the cell value if there was no item. There were 17 mathematical topics (Korea) and 19 mathematical topics (China) (Tables 3 and 5). Thus, there were 85 (17 topics with 5 cognitive demand levels) cells for Korea and 95 (19 topics and 5 cognitive levels) for China.

IV. RESULTS AND DISCUSIONS

1. TOPIC LEVEL ALIGNMENT

Table 2 shows the SEC indices for the CSAT. Indices show a pretty consistent level of alignment in the last three years. About 62% to 70% of mathematics items in the CSAT are aligned with the Korean mathematics curriculum standards; however, these values are lower than the critical value (Fulmer, 2011).

Table 2. Topic level SEC indices between the Korean curriculum standards and the CSAT mathematics items

	CSAT 2017	CSAT 2016	CSAT 2015
SEC Index	.619	.697	.684

The two most emphasized topics in Korean mathematics curriculum standards are permutation and combination (9.3%) and series and sequences (8.33%). In the last three years of the CSAT, 10%, 4%, and 4% of items were permutation and combination while series and sequences items were included 0%, 7%, and 11% each year, respectively. The most frequently assessed topics in the CSAT were probability (18% in 2017), integration (13% in 2016) and differentiation (11% in 2015). These three topics were covered 7%, 5% and 7% in Korean curriculum standards respectively. There are discrepancies and inconsistency between what the curriculum standards emphasize and what is being assessed in the CSAT. Table 3 shows the absolute discrepancy (absolute value of the difference between the proportion of topics covered in the standards and assessed in the CSAT) for each mathematical topic found in the Korean curriculum standards and the CSAT. Integration and Probability in 2017 and Limits in 2016 and 2015 are the mathematical topics with the largest absolute values. In addition, five standard topics (continuous functions, functions, logic, sets, and rational and radical functions) were not assessed at all during these three years.

Table 3. Absolute discrepancies by mathematical topics

Mathematics Topic	CSAT 2017	CSAT 2016	CSAT 2015
Conic Sections	0.027	0.057	0.017
Continuous Functions	0.021	0.021	0.021
Differentiation	0.067	0.002	0.037
Exponential and Logarithmic Functions	0.002	0.037	0.057
Functions	0.031	0.03	0.031
Geometry of Space	0.057	0.027	0.027
Integration	0.107	0.077	0.047
Limits	0.083	0.081	0.083
Logic	0.052	0.052	0.052
Permutation and Combination	0.006	0.053	0.053
Probability	0.107	0.012	0.037
Rational and Radical Functions	0.021	0.009	0.009
Series and Sequence	0.083	0.013	0.026
Sets	0.031	0.031	0.031
Statistics	0.042	0.032	0.042
Vector	0.012	0.017	0.017
Trigonometric Functions	0.007	0.047	0.037

Table 4 shows the content level alignment indices for the NCEE. These indices are similar to indices from the CSAT. Topics in the Chinese curriculum standards and the

NCEE are aligned with each other about 60% to 68%, which is similar to the Korean SEC indices. These values were also lower than the critical value (Fulmer, 2011).

Table 4. Topic level SEC indices between the Chinese curriculum standards and the NCEE mathematics items

	NCEE 2017	NCEE 2016	NCEE 2015
SEC Index	.683	.660	.600

The two most emphasized topics in Chinese mathematics curriculum standards are geometry of space (14%) and statistics (11%). Topics involving geometry of space were assessed 10%, 18.8%, and 21% each year and topics involving statistics were assessed 7% each year. Topics involving trigonometric functions were mostly frequently assessed in two of the three years (2016 and 2017) and geometry of space was the most frequently assessed topic in 2015. Similarly, these results reveal discrepancies and inconsistency between what the curriculum standards emphasize and what is being assessed in the NCEE. Table 5 presents the absolute discrepancy for each mathematical topic found in the Chinese curriculum standards and the NCEE. Trigonometric functions in 2017 and 2016 and vectors in 2015 had the largest absolute values. In addition, six standards topics (functions, permutation and combination, continuous functions, derivative, integration, and quadratic equations and inequalities) were not assessed at all in these three years.

Table 5. Absolute discrepancies by mathematical topics

Mathematics Topic	NCEE 2017	NCEE 2016	NCEE 2015
Functions	0.044	0.049	0.019
Complex Numbers	0.024	0.004	0.004
Continuous Functions	0.009	0.009	0.009
Permutation and Combination	0.014	0.014	0.014
Differentiation	0.032	0.002	0.061
Equations and Inequalities	0.021	0.049	0.078
Geometry of Space	0.035	0.046	0.075
Integration	0.019	0.019	0.019
Limits	0.039	0.039	0.039
Logic	0.033	0.000	0.029
Conic Sections	0.068	0.061	0.084
Exponential and Logarithmic Functions	0.003	0.024	0.034
Probability	0.035	0.039	0.039
Quadratic Equations and Inequalities	0.014	0.014	0.014
Series and Sequences	0.013	0.009	0.021
Sets	0.003	0.004	0.034
Vectors	0.101	0.102	0.132
Statistics	0.037	0.042	0.042
Trigonometric Functions	0.124	0.144	0.044

2. COGNITIVE DEMAND ALIGNMENT

Table 6 displays the alignment indices for cognitive level. About 44.4% to 49.7% of mathematical tasks in the CSAT are aligned to what the Korean mathematics curriculum standards expect students to know. All of the indices are less than the results from previous studies (Liu & Fulmer, 2008; Lu & Liu, 2012) and also, they are less than the critical value (Fulmer, 2011). These results indicate there are discrepancies between what is demanded cognitively from students on the assessment and what students are expected to know and do as stated in the curriculum standards.

Table 6. Cognitive level SEC indices between Korean curriculum standards and CSAT mathematics items

	CSAT 2017	CSAT 2016	CSAT 2015
SEC Index	.444	.497	.483

Figure 4 compares cognitive demand between the Korean curriculum standards and the CSAT. There are more performing procedures items in the CSAT compared to the curriculum standards, which partially agrees with previous studies that found the assessments to include more items with higher demand.

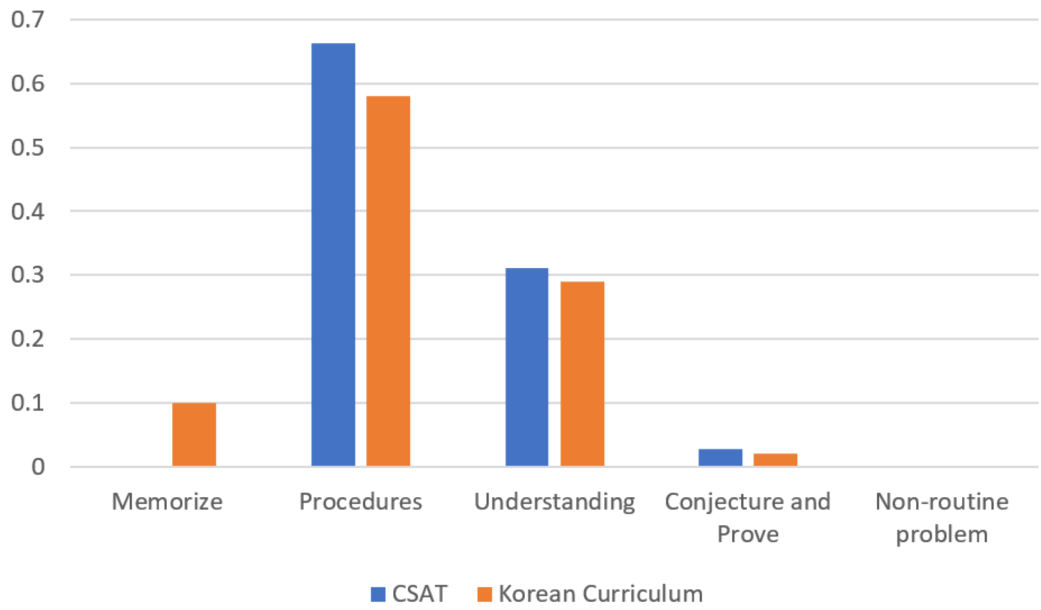

Figure 4. Comparison between the CSAT and the Korean curriculum standards by cognitive level

Table 7 shows similar alignment indices for cognitive level. Around 45.8% to 52.4% of mathematical tasks in the NCEE are aligned to what the Chinese mathematics curriculum standards expect students to know. Again, these indices are lower than the indices reported in previous studies (Liu & Fulmer, 2008; Liu et al., 2009; Ma et al., 2013) and also, less than the critical value (Fulmer, 2011).

Table 7. Cognitive level SEC indices between the Chinese curriculum standards and the NCEE mathematics items

	NCEE 2017	NCEE 2016	NCEE 2015
SEC Index	.524	.506	.458

Figure 5 compares the Chinese curriculum standards and the NCEE on cognitive level. The NCEE includes more items with performing procedures, partially agreeing with what previous studies found that the assessments include more items with higher demand.

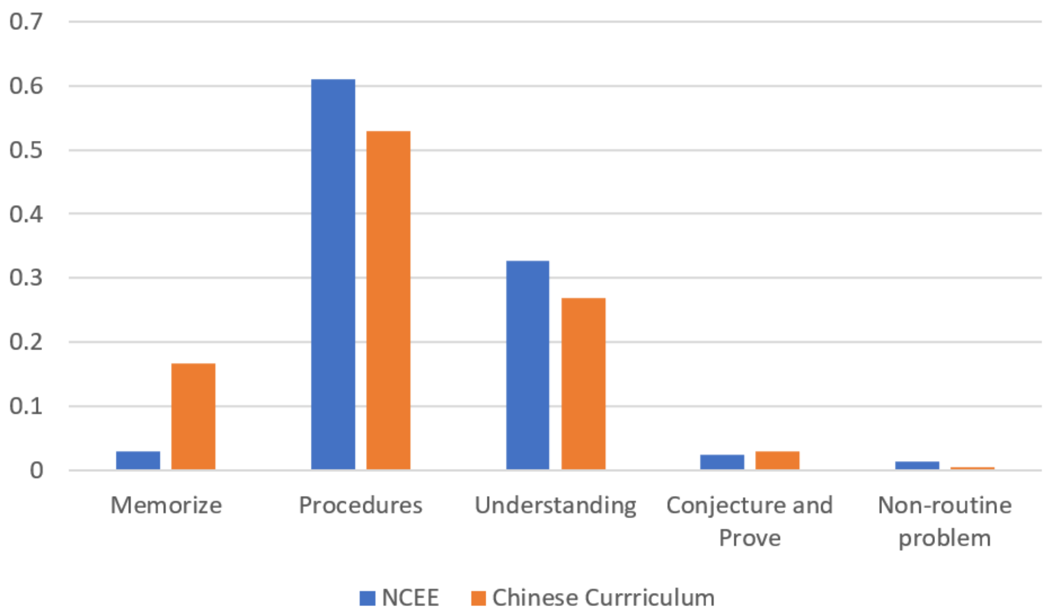

Figure 5. Comparison between the NCEE and the Chinese curriculum standards by cognitive level

3. COMPARION BETWEEN KOREA AND CHINA

Table 8 compares the CSAT and the NCEE by cognitive demand. These two high stakes assessments show a very similar distribution of items by cognitive demand. 66% of items in the CSAT are perform procedures while 61% of items in the NCEE are categorized as perform procedures (63.8% vs. 66.3% of low-level thinking items in NCEE and CSAT respectively). 32.7% (NCEE) and 31% (CSAT) of items are about demonstrating understanding and around 2% of items are about making conjecture or prove.

Table 8. Percent distribution of cognitive level items in the NCEE and the CSAT

	Memorize	Procedures	Understanding	Conjecture and Prove	Non-routine problem
NCEE	0.029	0.609	0.327	0.024	0.013
CSAT	0.000	0.663	0.310	0.026	0.000

Table 9 compares the Korean and Chinese curriculum standards by cognitive demand. We notice similarities between the distributions of standards by cognitive demand. The Chinese curriculum standards include more memorize items than the Korean standards and the Korean standards include more perform procedures items (69.6 % vs. 69% of standards statement require low – level thinking). Overall, the distribution of items by cognitive demand between the two countries are quite similar.

Table 9. Percent distribution of cognitive level standards in the Chinese and Korean curriculum standards

	Memorize	Procedures	Understanding	Conjecture and Prove	Non-routine problem
Chinese Curriculum	0.167	0.529	0.269	0.029	0.004
Korean Curriculum	0.100	0.580	0.290	0.020	0.000

From Tables 8 and 9, in both the curriculum standards and college entrance examinations, almost 70% of standards and items require low-level thinking. Although promoting high-level thinking is emphasized in both countries (Hwang & Han, 2014; Lv & Cao, 2018), it is not well reflected in their standards and assessments.

V. CONCLUSIONS

In this study, we examined the alignment between mathematics curriculum standards and college entrance examinations from Korea and China. The results indicate that curriculum standards and high stakes assessments from both countries are not well aligned to each other. Their SEC indices were lower than what previous studies have found and the critical values (Fulmer, 2011; Liu & Fulmer, 2008; Liu et al., 2009). There are several topics that are not assessed in the CSAT and the NCEE. Also, discrepancies between the most frequently covered topics in the curriculum standards and the most frequently assessed mathematical topics in the CSAT and the NCEE caused topic level misalignment. We also found misalignment in cognitive level. Both the CSAT and the NCEE included more perform procedures and demonstrate understanding items than their respective curriculum standards. Thus, previous findings about the inclusion of more items with higher cognitive demand in science assessments is only partially true for either country.

Using these results, we can think about the following important issues. College entrance examinations greatly influence teachers' class instructions in both Kores and China (Hong & Choi, 2011; Tu, 2018; Wang et al., 2018). How students do on the CSAT and the NCEE influence the school's reputation and also teachers' merit pay (China) as well as determines the effectiveness of their teaching (Tu, 2018). Thus, it is difficult to say that whether mathematical topics in the curriculum standards appropriately represent and support students to do well on the CSAT and the NCEE or that the mathematical items in the CSAT and the NCEE validly assess students' level of mathematical understanding. One of the main purposes of the CSAT and the NCEE is to see if students are ready to take college level classes (Nam, 2014; Tu, 2018). Since mathematical content of both the CSAT and the NCEE are based on their respective mathematics curriculum standards (Nam, 2014; Tu, 2018), one may think that what Korean and Chinese students expect from their respective curriculum standards is enough for them to do well on these high stakes assessments. However, our analysis reveals it is unlikely that students can do well on these assessments with what they can learn according to their respective curriculum standards. We may also need to define what it means by college–readiness, but it is clear that both Korean and Chinese students need additional support to do well on the CSAT and the NCEE because at both the topic and cognitive level, what students expect from their respective curriculum standards and what they are being assessed by their college entrance examinations are not exactly the same. Because of misalignment, it is possible that teachers can only teach to the CSAT or the NCEE, meaning that what they implement in their mathematics classes is not consistent with their curriculum standards, causing misalignment at classroom level. When teachers teach to the assessments, they can narrow their teaching to only tested topics and often use teacher–centered teaching (Liu et al., 2009). For example, those topics that were not assessed in the CSAT and the NCEE may not be taught and emphasized often during their classes. In fact, many Korean students receive additional instructional support outside of school (Nam, 2014), which shows that Korean students are getting additional support to do well on CSAT.

There are several directions for future research. One important issue is to investigate content validity (Beck, 2007). Although it is beyond the scope of this study, we should think about validity of mathematical content for both Korea and China. That can lead to possible areas of investigating curriculum in different stages. Are Korean and Chinese students validly assessed by the CSAT and the NCEE? Both content and cognitive level should be examined to understand validity. Teachers' classroom practices also need to be considered. In the process of lesson planning and implementing, enacted curriculum shows a lot about how and what teachers do. Thus, examining teachers' instructional practices to understand alignment will be an important area to explore. Are teachers aware of the differences between the expectations of standards and high-stakes assessments? If they are, how does that affect what and how they teach? As we did with curriculum standards and assessment, we can look at both topic and cognitive level coverage to determine if teachers really teach to the test. We can also examine textbook coverage of mathematics topics since they are an important resource in the lesson planning process. Textbooks are often called potentially implemented curriculum (Valverde, Bianchi, Wolfe, Schmidt, & Houang, 2002) and how textbooks cover mathematical topics can influence teachers' lesson plans and their instructional practices. How well aligned are mathematical textbooks to mathematics curriculum standards? Answering these questions will allow mathematics educators to close the gaps between curriculum standards and national assessments.

An interesting finding from this study is the similarity between Korea and China. Their SEC indices were very similar for all three years (in both curriculum standards and assessments). The percent distribution of cognitive level was very comparable as well. Additionally, there are several topics that were not included during these three years. These are two countries that historically have high performances on international comparative studies and whose college entrance examinations greatly influence school mathematics. In previous studies, educational researchers found a similar structure in curriculum standards of East Asian countries (Schmidt et al., 2005). Schmidt and his colleagues claimed that the more coherent curriculum structures of East Asian curriculum standards is one reason for their high performances. Additionally, researchers often claim that including more items with higher level thinking in mathematics textbooks can be one possible reason for East Asian students' high performances (Son & Senk, 2010) while other researchers claimed that it might be more complex to understand TIMSS and PISA results than what ranking and scores indicate (Cai, 2005; Cai & Nie, 2007). Our results in this study show that there are some common features in high stakes assessments and curriculum standards but they are not aligned well and many standards statements and mathematics items in assessments required lower level thinking. With our results, although we do acknowledge that participating students for TIMSS and PISA are younger than those who take CSAT and NCEE, it is difficult to say that assessments and curriculum standards of Korea and China can be contributing factors of their high performances. As we mentioned earlier both Korean and Chinses students might have additional support to be prepared for CSAT or NCEE. As we previously mentioned, high stakes assessments greatly influence teaching practices. What types of additional support do Korean and Chinese students get outside of their schools? Do teachers teach for high stakes assessments? These are some important questions that we might need to explore further to try to understand mathematics education in East Asian countries. Thus, it is worthwhile to explore this topic of similarity further so that we can understand factors that can influence East Asian students' performances.

REFERENCES

Au, W. (2007). High-stakes testing and curricular control: A qualitative metasynthesis. *Educational Researcher, 36*(5), 258-267. doi:10.3102/0013189x07306523

Beck, M. D. (2007). Review and other views: "Alignment" as a psychometric issue. *Applied Measurement in Education, 20*(1), 127-135. doi:10.1080/08957340709336733

Bhola, D. S., Impara, J. C., & Buckendahl, C. W. (2003). Aligning tests with states' content standards: Methods and issues. *Educational Measurement: Issues and Practice, 22*(3), 21-29. doi:doi:10.1111/j.1745-3992.2003.tb00134.x

Cai, J. (2005). U.S. and Chinese teachers' constructing, knowing, and evaluating representations to teach mathematics. *Mathematical Thinking and Learning, 7*(2), 135-169. doi:10.1207/s15327833mtl0702_3

Cai, J., & Nie, B. (2007). Problem solving in Chinese mathematics education: Research and practice. *ZDM, 39*(5), 459-473. doi:10.1007/s11858-007-0042-3

Fulmer, G. W. (2011). Estimating critical values for strength of alignment among curriculum, assessments, and instruction. *Journal of Educational and Behavioral Statistics, 36*(3), 381-402. doi:10.3102/1076998610381397

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076-1100. doi:doi:10.1002/tea.21481

Heck, D. J., Weiss, I. R., & Pasley, J. D. (2011). *A priority research agenda for understanding the influence of the Common Core State Standards for Mathematics*. Retrieved from Chapel Hill, NC: http://www.horizon-research.com/reports/2011/CCSSMresearchagenda/research_agenda.pdf

Herman, J. L., & Webb, N. M. (2007). Alignment methodologies. *Applied Measurement in Education, 20*(1), 1-5. doi:10.1080/08957340709336727

Herman, J. L., Webb, N. M., & Zuniga, S. A. (2007). Measurement issues in the alignment of standards and assessments. *Applied Measurement in Education, 20*(1), 101-126. doi:10.1080/08957340709336732

Hong, D. S. (2011). Best known problem solving strategies in 'high-stakes' assessments. *International Journal of Mathematical Education in Science and Technology, 42*(6), 823-829.

doi:10.1080/0020739X.2011.562321

Hong, D. S., & Choi, K. M. (2011). Korean college entrance exams: An inside look. *The Mathematics Teacher, 105*(3), 208-213. doi:10.5951/mathteacher.105.3.0208

Hong, D. S., & Choi, K. M. (2014). A comparison of Korean and American secondary school textbooks: The case of quadratic equations. *Educational Studies in Mathematics, 85*(2), 241-263. doi:10.1007/s10649-013-9512-4.

Hong, D. S., & Choi, K. M. (2018). A comparative analysis of linear functions in Korean and American standards-based secondary textbooks. *International Journal of Mathematical Education in Science and Technology, 49*(7), 1025-1051. doi:10.1080/0020739X.2018.1440327

Hong, D. S., Choi, K. M., Runnalls, C., & Hwang, J. (2018). Do textbooks address known learning challenges in area measurement? A comparative analysis. *Mathematics Education Research Journal, 30*(3), 325-354. doi:10.1007/s13394-018-0238-6

Hwang, H., & Han, H. (2014). *Current national mathematics curriculum*. Hackensack, UNITED STATES: World Scientific Publishing Co Pte Ltd.

Liang, L. L., & Yuan, H. (2008). Examining the alignment of Chinese national physics curriculum guidelines and 12th□grade exit examinations: A case study. *International Journal of Science Education, 30*(13), 1823-1835. doi:10.1080/09500690701689766

Liu, X. (1996). *Mathematics and science curriculum change in the People's Republic of China.* Lewiston, NY: Edwin Mellen.

Liu, X., & Fulmer, G. (2008). Alignment between the science curriculum and assessment in selected NY State regents exams. *Journal of Science Education and Technology, 17*(4), 373-383. doi:10.1007/s10956-008-9107-5

Liu, X., Zhang, B., Liang, L. L., Fulmer, G., Kim, B., & Yuan, H. (2009). Alignment between the physics content standard and the standardized test: A comparison among the United States□New York State, Singapore, and China□Jiangsu. *Science Education, 93*(5), 777-797. doi:doi:10.1002/sce.20330

Lu, Q., & Liu, E. (2012). Alignment between high school biology curriculum standard and the standardised tests of four provinces in China. *Journal of Biological Education, 46*(3), 149-164. doi:10.1080/00219266.2011.645855

Lv, S.-h., & Cao, C. (2018). The evolution of mathematics curriculum and teaching materials in secondary schools in the twenty-first century. In Y. Cao & F. K. S. Leung (Eds.), *The 21st century mathematics education in China* (pp. 147-169). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ma, H., Fulmer, G. W., Liang, L. L., Chen, X., Li, X., & Li, Y. (2013). An alignment analysis of junior high school chemistry curriculum standards and city-wide exit exams in China. In M.-H. Chiu, H.-L. Tuan, H.-K. Wu, J.-W. Lin, & C.-C. Chou (Eds.), *Chemistry education and sustainability in the global age* (pp. 157-169). Dordrecht: Springer Netherlands.

Martone, A., & Sireci, S. G. (2009). Evaluating alignment between curriculum, assessment, and instruction. *Review of Educational Research, 79*(4), 1332-1361.

doi:10.3102/0034654309341375

Ministry of Education in Korea. (2011). *The mathematics curriculum standards*. Retrieved from Seoul, Korea: http://ncic.go.kr/mobile.revise.board.list.do

Mullis, I. V. S., Martin, M. O., Foy, P., & Arora, A. (2012). *The TIMSS 2011 international results in mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics*. Retrieved from Boston College: http://timssandpirls.bc.edu/timss2015/international-results/

Nam, J. (2014). Mathematics test in the CSAT. In J. Kim & H. Han (Eds.), *Mathematics education in Korea* (pp. 289-306). Hackensack, NJ: World Scientific Publishing.

Newton, J., & Kasten, S. (2013). Two models for evaluating alignment of state standards and assessments: Competing or complementary perspectives? *Journal for Research in Mathematics Education, 44*(3), 550-580. doi:10.5951/jresematheduc.44.3.0550

Organisation for Economic Cooperation and Development [OECD]. (2015). *Database-PISA 2015*. Retrieved from http://www.oecd.org/pisa/pisa-2015-results-infocus.

Polikoff, M. S. (2015). How well aligned are textbooks to the Common Core Standards in Mathematics? *American Educational Research Journal, 52*(6), 1185-1211. doi:10.3102/0002831215584435

Polikoff, M. S., Porter, A. C., & Smithson, J. (2011). How well aligned are state assessments of student achievement with state content standards? *American Educational Research Journal, 48*(4), 965-995. doi:10.3102/0002831211410684

Resnick, L. B., Rothman, R., Slattery, J. B., & Vranek, J. L. (2004). Benchmarking and alignment of standards and testing. *Educational Assessment, 9*(1-2), 1-27. doi:10.1080/10627197.2004.9652957

Schmidt, W. H., & Prawat, R. S. (2006). Curriculum coherence and national control of education: issue or non□issue? *Journal of Curriculum Studies, 38*(6), 641-658. doi:10.1080/00220270600682804

Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies, 37*(5), 525-559. doi:10.1080/0022027042000294682

Son, J.-W., & Hu, Q. (2016). The initial treatment of the concept of function in the selected secondary school mathematics textbooks in the US and China. *International Journal of Mathematical Education in Science and Technology, 47*(4), 505-530. doi:10.1080/0020739X.2015.1088084

Son, J.-W., & Senk, S. L. (2010). How reform curricula in the USA and Korea present multiplication and division of fractions. *Educational Studies in Mathematics, 74*(2), 117-142. doi:10.1007/s10649-010-9229-6

Tu, R. (2018). Primary and secondary mathematics selective examinations. In Y. Cao & F. K. S. Leung (Eds.), *The 21st century mathematics education in China* (pp. 453-478). Berlin, Heidelberg: Springer Berlin Heidelberg.

Tyler, R. (1949). Basic principles of curriculum and instruction. In. Chicago: University of Chicago Press.

Valverde, G., Bianchi, L. J., Wolfe, R. G., Schmidt, W. H., & Houang, R. T. (2002). *According to the book: Using TIMSS to investigate the translation of policy into practice through the world of textbooks*. Dordrecht, Netherlands: Kluwer.

Wang, L., Liu, Q., Du, X., & Liu, J. (2018). Chinese mathematics curriculum reform in the twenty-first century. In Y. Cao & F. K. S. Leung (Eds.), *The 21st century mathematics education in China* (pp. 53-72). Berlin, Heidelberg: Springer Berlin Heidelberg.

Webb, N. L. (1997a). *Criteria for alignment of expectations and assessments in mathematics and science education*. Madison, WI: University of Wisconsin–Madison, Wisconsin Center for Education Research.

Webb, N. L. (1997b). Determining alignment of expectations and assessments in mathematics and science education. *NISE Brief, 1*(2), 1-8.

Webb, N. L. (1999). *Alignment of science and mathematics standards and assessments in four states (Research Monograph No. 18).* Madison, WI: University of Wisconsin–Madison, National Institute for Science Education.

Webb, N. L. (2007). Issues related to judging the alignment of curriculum standards and assessments. *Applied Measurement in Education, 20*(1), 7-25. doi:10.1080/08957340709336728