CHAPTER 6

MOTIVATION FOR ABACUS STUDIES AND SCHOOL MATHEMATICS

A Longitudinal Study of Japanese 3rd–6th Graders

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ABSTRACT

Japan's informal educational system, which functions independently of its formal educational system, includes preparatory schools, cram schools, specialized classrooms and other facilities. This variety of after-school facilities assist children with preparation for entrance examinations for school admissions, and training in academic and non-academic skills, sports, and hobbies. Shwalb, Sugie, and Yang focus on Japan's abacus juku and consider how study at this institution influences mathematics learning and motivation in formal school settings. They also consider the views of children, parents and teachers regarding the existence of a "mental abacus." Their longitudinal data suggest that abacus juku exert a positive influence on school mathematics education. This study is a rare example of research on the connections between formal and informal schooling.

Applied Developmental Psychology in Japan, pages 109–135

INTRODUCTION

Researchers have reported for several decades that Japanese elementary school children excel in international comparisons of mathematics achievement (e.g., Stevenson & Lee, 1990). This phenomenon has led researchers to conduct cross-national studies showing the positive influences of home environment (Azuma, 1996) and instructional quality (Stigler & Hiebert, 1999) on Japanese children. But at the same time that Western scholars have focused on the strengths of Japanese education from preschool (Peak, 1992) through high school (Rohlen, 1983), Japanese educators have been self-critical and looked to the West for models of educational reform.

Compulsory versus Supplementary Education

Compulsory school education. Japanese elementary school grades may be divided into three segments: grades 1–2 (lower), 3–4 (middle), and 5–6 (upper elementary). The focus in grades 1 and 2 is on basic skills (the 3 R) and on motivation, with an emphasis on activity- and experience-based learning appropriate for the transition to Piaget's concrete operational stage. Grades 3 and 4 mark a transition to upper elementary school, where learning becomes more complex for learning in the latter phase of the concrete operational period. Few individual differences in academic performance appear before grade 4, but in upper elementary school individual differences become more notable. From 5th grade children study an increasingly abstract curriculum and solidify their skills before entering junior high school, which is also compulsory. Junior high curriculum is abstract and challenging, which corresponds to children transition to formal operational thinking. Because parents do not want their children to enter secondary school with any academic disadvantage, many enroll them in *juku* to supplement their compulsory school education.

Supplementary juku education. Studies on achievement have focused on compulsory educational settings, but our research took place mainly at *juku* (塾). *Juku* has received less attention from scholars because they are not officially part of the formal educational system, even though *juku* education may reinforce children's mastery of school learning. The main type of *juku* is the academic *juku*, of there are two varieties: *juken juku* (受験塾) where children prepare for entrance examinations to junior and senior high school, and *hoshu juku* (補習塾) which help children who have difficulty at regular school review and preview their formal school materials. Abacus *juku* (along with those for computing, graphics, etc.) fit into a separate category called *senmon juku* (専門塾), which teach children basic skills relevant to school learning but not actually materials from the formal curriculum. A third classification of supplemental education is called *kyoshitsu* (教室) or classroom; these run programs for sports, martial arts, dance, music, tea ceremony, flower arrangement, etc., which are not academic in content.

An additional supplemental educational institution is the *yobiko* (予備校, literally "preparatory school"), which is often attended full-time by high school graduates who were unable to gain admission to their desired colleges and prepare to retake entrance examinations (Tsukada, 1988). Some high school students attend *yobiko* part-time in the evenings after regular school. We believe supplemental education is an important aspect of learning and development in Japan (Ukai, 1994).

Abacus education. The abacus (in Japanese called either *soroban*—literally calculation panel—算盤, or *shuzan*—literally bead-calculation—珠算) was taught in Japan since the 17th century (Shin Kyoikugaku Daijiten, 1990). During the Edo Period (1602–1868), mathematics instruction at small private schools called *terakoya* was all conducted on the abacus. Textbooks for abacus studies also appeared from the early 1600s. During the Meiji Period (1868–1912) of westernization, abacus was omitted from mathematics studies because it was thought to be a pre-modern Japanese method of calculations, whereas mathematics textbooks focused on Western mathematics. However, from 1926 abacus instructions became mandatory at the upper grades of compulsory elementary school. It was taught from textbooks in the mid-1930s during a period of nationalism, and seen as a positive aspect of traditional Japanese culture (Shin Kyoikugaku Daijiten, 1990). At that time children learned to add and subtract by abacus in the 4th grade and to multiply and divide in the 5th grade. The postwar 1951 reform of the curriculum limited abacus training to only addition and subtraction between 4th and 6th grade. Despite all these changes, Japanese throughout most of the 20th century acquired basic abacus skills at school and the abacus was a popular device at stores, companies, and schools.

With the rising popularity of microcomputers in the 1980s, the abacus gradually lost its place in the work world. Accordingly it has been phased out of the school curriculum and is now taught only briefly in the 3rd grade. In today's public school curriculum pupils learn how to handle the abacus, express numbers, and make simple addition and subtraction calculations (Ministry of Education, Culture, Sports, Science, and Technology, 1998). But this instruction is probably more of an exposure to an aspect of Japanese traditional culture than an aspect of actual mathematics education. Another reason abacus education is minimized in today's schools is that mathematics education itself has shifted its focus from calculation to conceptual understanding. For most children, abacus is useful for basic arithmetic functions, but from upper elementary school the curriculum emphasizes more complex aspects of mathematics.

There are still abacus *juku* in every major Japanese city and town, and a scene from a typical suburban *juku* is shown in Figure 6.1. Attendance at abacus *juku* usually begins in 3rd grade, with a peak enrollment of 4th graders and a sharp enrollment decline thereafter. Very few abacus pupils attend *juku* for more than two years. Abacus *juku* are privately owned and operated, and teachers receive accreditation to teach from the League for Soroban Education in Japan ("LSEJ") through its regional divisions. Achievement in abacus studies is formalized in attaining ranks according to one's level of expertise. The lowest of the ranks is called "15-kyu" ("fifteenth-class") and requires only that one pass a 14-minute, 30-item test of very simple addition and subtraction. From the third-class examination and up, the test consists of 90 items and is about 40 minutes long. The precipitous increase in difficulty as students progress through these ranks is seen in comparing the pass rates on examinations last year: 6-kyu = 82%, 4-kyu = 51%, 1-kyu = 43% (Personal communication, LSEJ, July 22, 2003). Passing the third class examination indicates proficiency sufficient to use abacus in the workplace, and the rank of first-class is rarely attained. One would have to attend *juku* for 1~1.5 years for five hours weekly to achieve a third-class rank, and would need to maintain that pace for at least three full years to achieve the rank of first-class. Abacus teachers have attained ranks higher than 1-kyu, which are called by the suffix "-dan." The numbers of children studying abacus at *juku* has decreased steadily, declining by 86% from a peak of 3.1 million children who took exams to achieve rankings in 1983, to only 442,364 in the year 2002. This figure represents an even sharper drop than the 36% decrease in the size of the general population of elementary school children, from 11 million in 1983 to 7 million in

Figure 6.1. Elementary school children performing calculations at abacus *juku*. Photo courtesy of the League for Soroban Education of Japan, Inc.

2003 (Personal communication, LSEJ, July 22, 2003). Even the physical composition of the abacus itself has changed in Japan. Prior to World War II the abacus used in most commercial settings had five beads in its lower tray, but after the war it became more common to use an abacus with only four beads in the lower tray.

Relation Between Abacus and Mathematics Skills

Hatano (1989) wrote that paper and pencil calculations are never taught at abacus *juku,* and that children never use an abacus for calculations in regular school mathematics classes. Hatano therefore called school mathematics and *juku* abacus learning "two microworlds of computation" (p. 15). In the microworld of elementary school mathematics, educators distinguish between calculations (*keisan* or 計算) and mathematics (*sansuh* or 算数). Paper-and-pencil calculations at school are called written math (*hissan* or 筆算). Since both abacus and paper-and-pencil calculations have the same goal (a correct answer), we may presume that procedures learned at school and *juku* are related. Hatano concluded that "development of mathematical cognition can be conceptualized as a process of interaction between non-school and school math procedures" (p. 18), and that abacus learning has "limited instructional value" because it emphasizes proficiency (speed) over comprehension (conceptualization).

Previous research on the relationship between mathematics and abacus has focused on "skills." For example, Stigler, Chalip, and Miller (1986) concluded from their research on Taiwanese 5th graders that children studying abacus developed a "mental abacus" that changed their "representations of mental calculation" (p. 447). Specifically, they related abacus training to special conceptual representations of mathematical knowledge and to calculations skills. In another study in Taiwan, Miller and Stigler (1991) found that a higher level of abacus calculation skills resulted in formation of a mental abacus, and that abacus training changed children's reaction times in mental calculations. What is a "mental abacus?" It is a specific type of mental calculation when the individual imagines or visualizes rows of abacus beads while solving problems. This is illustrated in Figure 6.2 by a group of abacus *juku* pupils who practiced "mental calculations" by moving their fingers in the air in the same motion they would make to perform a calculation with an abacus, as the teacher read them a list of numbers to calculate. Mental calculation itself can take various forms depending on the individual, e.g., visualizing actual numbers while making a calculation. Researchers, however, have not studied whether children who use a mental abacus exclude or downplay other forms of mental calculation or strategies.

Figure 6.2. Abacus *juku* students perform calculations on a "mental abacus" by visualizing an abacus while their teacher reads them a column of numbers to add. Photo courtesy of the League for Soroban Education of Japan, Inc.

Motivational Theory and Research

Competence beliefs and task values. We were interested in motivational aspects of abacus education. Specifically, we investigated motivation for mathematics and abacus in terms of "subjective task values" and "competence beliefs" (Eccles, Wigfield, & Schiefele, 1997; Wigfield, Eccles, Yoon, Harold, Arbreton, Freedman-Doan, & Blumenfeld, 1997). Key constructs of the theoretical model of Eccles and her associates were (a) competence beliefs, i.e., self-estimations of ability, and (b) subjective task values, i.e., incentives for performing tasks, including interest in a task, importance of the task, and perceived usefulness of the task. According to the model, beliefs and values are based on children's previous performance and feedback from teachers, parents and others, and children do better on and are motivated to select challenging tasks when they believe they are able to accomplish the particular task.

Wigfield et al. (1997) studied changes in competence beliefs and subjective task values in several domains including school mathematics, with a longitudinal sample of 514 American children. They found that in upper elementary school children's beliefs and values became more stable than in lower elementary school, and that with age children's beliefs about their own competence increasingly related to estimates of children's competence by teachers and parents. In their sample, competence beliefs and ratings of the usefulness and importance of mathematics gradually decreased over the elementary school years, yet interest in mathematics did not decrease with age. They also observed cohort effects on competence beliefs, and that across grade levels boys had more positive competence beliefs than did girls for mathematics. Wigfield et al. concluded that beliefs were established during elementary school and that children's self-evaluations became more realistic with age. Overall they found a decline in competence beliefs and in perceptions of mathematics as useful or important.

In another study of American children, Jacobs, Lanza, Osgood, Eccles, and Wigfield (2002) used a cross-sequential design to study task values and competence beliefs in grades 1–12 ($n = 761$) in several domains including mathematics. As in Wigfield et al. (1997), they noted a decline through elementary school in self-perceptions of competence and task values for mathematics. Also similar to Wigfield et al., they found that while boys had more positive perceptions of their mathematics competence in first grade than girls, boys' competence beliefs declined more rapidly than girls' in elementary school. Jacobs et al. concluded that declining competence beliefs account for age-related declines in task values.

Attributions. Holloway's (1988) comparative review of research on attributions by American and Japanese children suggested that Japanese schools and families encourage children to view effort as the primary cause of achievement, more than is the case in the United States. Similarly, Stevenson (1992) wrote that traditional Japanese culture has valued effort and diligence, and asserted that individual differences in ability have traditionally been downplayed in Japan. In line with these cultural differences in attributions, more Japanese children and parents in Stevenson's three-culture study (Japan, Taiwan, the United States) agreed that anyone could achieve well in mathematics if they tried hard enough, and that everyone in their class had equal mathematics ability, compared with Americans' views (Stevenson & Lee, 1990).

OUR LONGITUDINAL STUDY

With regard to motivation for abacus and mathematics learning, we first investigated the relationship between five theoretical constructs: children's recognition of the existence of a mental abacus belief, parental and teacher evaluation of children's ability, children's ability self-concepts and values (interest in and importance of abacus and mathematics tasks). Second, we collected both cross-sectional and longitudinal data to compare several motivational constructs across the middle and upper elementary school years. Third, we explored the influence of abacus studies on several child characteristics, based on a factor analysis. Fourth, by comparing data from children at *juku* with responses from children who did not attend abacus *juku*, we considered how motivation for mathematics is influenced by attending abacus *juku*. In addition, we looked at children's attributions for success and failure on mathematics and abacus tasks, their perceptions of abacus skills as gender-typed, and parental and teachers' perceptions of characteristics of and influences on superior abacus students.

METHODS

Participants and Procedures

Every school-age pupil in grades 3 through 6 at nine abacus *juku* (n = 452, with 245 females and 207 males) initially completed an Abacus Questionnaire (AQ), a 60-item form about their abacus studies. A month later they filled out a similar 45-item questionnaire about their study of mathematics at school (MQ). To compare the thinking of abacus *juku* students with same-age children who did not study abacus, a Control Group of every 3rd through 6th grade pupil (n = 546, with 291 females and 255 males) at two public elementary schools also completed the MQ. Pupils who reported on the MQ that they had studied abacus at a *juku* were eliminated from the Control Group for purposes of analysis; the reduced Control Group n was 336. Earlier the same week, fourteen teachers at the *juku* filled out 12-item Teacher Rating Questionnaire (TRQ), rating each pupil's study of abacus and mathematics. The teachers also completed a separate 10-item general Teacher Background Questionnaire (TBQ) about abacus education. At the beginning of the study, each child took home a Parent Questionnaire (PQ) for a parent to fill out; the PQ was similar in content to the AQ and provided parental ratings of each child. Parents of 396 abacus pupils (217 mothers and 179 fathers) completed the PQ (return rate = 87.6%).

Six months into the academic year, the 452 abacus pupils completed a follow-up questionnaire that included 35 AQ and six MQ items (AMQ). The 4th grade abacus cohort from the time of initial data collection (n = 160) also completed the AMQ when they became 5th graders (n after attrition = 114) and as 6th graders (n = 65). At every time of measurement, every child studying at the *juku* or schools took part in the survey during classroom time; teachers personally followed up with and collected data from any pupil who was absent on a day of data collection. Pupil response rates were therefore always 100%.

Child Questionnaires

Table 6.1 presents definitions and sample items for each construct. Questionnaire items were developed in reference to instruments used in past research on children's competence beliefs and task values (e.g., Wigfield et al., 1997). The AQ consisted of 52 items, of which eight were demographics, 23 were about motivation for abacus studies (ability self-concept, task values, etc.), 2 were about sex-typing, 7 about relationships with *juku* peers and teachers, 3 about mental abacus, 15 about influences of abacus studies, and 2 about the relation between school mathematics and abacus studies.

Table 6.1. Construct Definitions and Item Examples

Construct	*Definition*	*Examples of Questions*
Ability	Rating by teacher or parent of child's ability	Compared to other students, how well does she/he do at abacus?
		Is your child strong or weak in school math?
Ability Self-Concept	Belief that one is competent in studies and use of skills	Do you understand your abacus studies well?
		Are you fast at abacus?
Interest	Feelings of liking for abacus studies and the abacus *juku*	Is abacus fun?
		Is abacus interesting?
		Do you like studying at an abacus *juku*?
Utility Value	Value placed on the usefulness of studying abacus	How useful do you think abacus will be in your adult life?
		How useful is the abacus in society?
Attainment Value	Value placed on the usefulness of studying abacus	How do you feel when you solve an abacus problem perfectly?
		How important is it to solve abacus problems?
Effort	Desire to study hard in order to improve one's performance in abacus	When you do abacus at the *juku* [at home], how hard do you try?
Anxiety	Anxiety in relation to performance on abacus	When you take an abacus test, how nervous do you get before the test?
Success/Failure Attributions	Explanation for doing well or poorly on tests or in class	When you [do not] do well at abacus, what do you most often think of as the reason for [not] doing well?
Mental Abacus	Awareness of existence of mental abacus	Do you believe there is something like a "mental abacus" in your head?
		When you do math at school or home, do you ever imagine the image of abacus beads in your mind?

The MQ contained ten items about motivation toward school mathematics in general, 19 items about motivation toward calculations as a domain of mathematics studies, one question about mathematics word problems, one item each about sex differences in mathematics and calculations studies, and two items about the use of tutors and *juku* to study mathematics. The follow-up AMQ replicated most of the items from the initial AQ and six items from the MQ: liking, confidence, importance, ability self-concept, parental perceptions of the child's mathematics ability, and whether the child studied school mathematics at a *hoshu juku*.

Teacher Questionnaires

Student ratings. Teachers rated each individual student on 12 items: ability in mathematics; achievement, ability, liking, confidence, effort, anxiety, enjoyment of challenges, and competitiveness in abacus studies; and attendance record, sociability, and quality of relationship with the teacher.

Demographics. Teachers also described their own background and characteristics of abacus classes (size, organization, etc.). They also listed qualities of exceptional abacus students, influences on top students, and examples of the influence of abacus studies on school mathematics. The ten male and four female teachers averaged 53.7 years of age (range = ages 41–65) and 32.6 years of abacus teaching experience (range = 20–45 years). Only two of the fourteen had previously taught mathematics in schools. They averaged 20.9 hours (range = 5–30 hours) of weekly *juku* classroom instruction. The average class size was 34.6 students (mode = 40, range = 10–50 students).

Parent Questionnaire

The PQ consisted of 28 items, most of which were also on the AQ. For example, it asked about perceptions of the child's motivation for school mathematics and mathematics calculations (ability, attainment value, achievement expectations, and anxiety), and about parental involvement in the child's education. According to the PQ data, the modal head-of-household occupation was a company worker (n = 262 = 66.7% of families), followed in frequency by self-employed (47 = 12.0%) and civil servants (35 = 8.9% of families). Parents' most common educational aspiration for their children was college (52.2%), followed by junior college (24.7%), high school (14.1%) and technical college (5.3%). These demographics indicated that the sample was drawn from a middle class Japanese population.

Most parents (n = 299) reported that they had studied abacus themselves, and the most common ranks they had achieved were "2-kyu" and "3-kyu." A rank of 4-kyu requires relatively little study, a rank of 3-kyu represents a level of proficiency sufficient to use abacus in the workplace, a 2-kyu rank is a high level of attainment, a rank of 1-kyu is extremely difficult to attain. Parents had slightly lower aspirations for children's abacus studies (mean = 3.68 , mode = 3-kyu, SD = 1.63) than their own level of achievement (mean = 2.65 , SD = 1.24), t = 8.77, df = 292, p < .01. Their lower expectations for children may be due to the fact that many parents today do not understand the ranking system, or that the abacus is less useful in public today compared with in the parents' generation. Parents were asked how involved they were with their children's education, and how involved their parents had been with their own education, on a 5-point scale with 1 = very active and 5 = not active. Parents reported that they were more active in children's education (mean = 3.19, SD = 0.80, mode = 3 = a little active) than their parents had been (mean = 3.55, SD = 1.02 , mode = 4 = not very active, t = 6.32, df = 292, p < .01).

RESULTS

Model of Motivation for Abacus Studies

Measurement of abacus constructs. Confirmatory factor analyses examined the measurement properties of the respective dependent variable constructs. The first measurement model of the abacus constructs related (1) ability, (2) ability self-concept, (3) interest, and (4) value (attainment and utility combined). The indicators of each construct and standardized factor loadings are presented in Table 6.2. The correlations between the four constructs ranged from .11 to .57. The model fit the data satisfactorily, with χ^2 = 76.75, df = 59, p = .06, CFI = .98, TLI = .97, and RMSEA = .05, implying that the parameter estimates were reliable. The factor loadings were expected to change slightly over time (Pentz & Chou, 1994) and thus were not tested explicitly.

Model of relationship between mental abacus beliefs, parent/teacher evaluation of child's ability, ability self-concept, and task values. A measurement model was tested for the relationship between children's belief in the mental abacus, abacus ability (as rated by teachers and parents), interest, abacus ability self-concept, and attainment/utility values. Two mental abacus items were recoded to indicate whether or not children believed in and/or used a mental abacus, forming the "mental abacus" construct. Figure 6.3 illustrates that the model fit the data satisfactorily, with χ^2 = 208.41, df = 110, p < .001, CFI = .96, TLI = .95, RMSEA = .05. No child-gender difference was

Table 6.2. Factor Structure of Abacus Constructs

Factor	*Item Content*	*Factor Loadings*
Abacus Ability	Compared to other students, how well does he[she] do at abacus?	.96
	How good is he at math?	.98
	Is your child strong or weak in abacus studies?	.46
Self-Concept of Ability	Are you fast at abacus? Slow?	.70
	Do you understand your abacus studies well? Not so well?	.52
	Compared with other children, how good are you at abacus studies?	.75
	What do your parents seem to think about how you are doing in your abacus studies?	.61
Abacus Interest	Do you like doing abacus? Dislike?	.89
	Is abacus fun? Not fun?	.82
Attainment and Utility Value	How do you feel when you solve a abacus problem?	.87
	How important is it for you to solve abacus problem	.73
	How useful is abacus in society?	.77
	When you take a "kentei" (ranking) abacus test, How important it is to you personally to do well?	.91

found for parents' or teachers' ratings of children's abacus abilities. Children's belief in the mental abacus was associated with abacus ability as rated by parents and teachers ($\beta = .55$, $z = 3.63$, $p < .01$), which was associated with children's self-concept of abacus ability ($\beta = .84$, $z = 3.67$, $p < .01$). Ability self-concept in turn predicted children's valuing of abacus ($\beta = .65$, $z = 7.40$, $p < .01$). Factor loadings of interest and attainment/utility value were .84 and .66, respectively. This model was also tested with children's gender as a predictor of parent/teacher ability ratings, but there was little association ($\beta = .03$) between the model and gender.

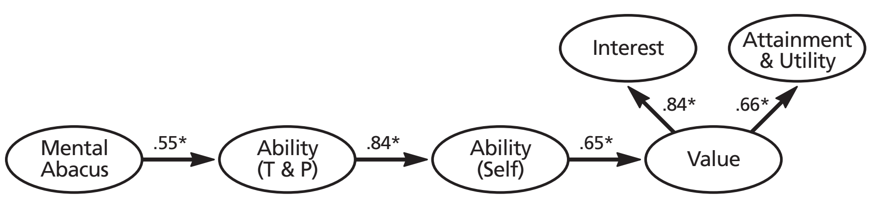

Figure 6.3. Model of relationship between awareness of mental abacus, parent/teacher perceptions of ability, ability self-concept and value for abacus studies.

Longitudinal analyses. Developmental trends in children perceptions of abacus ability self-concept, interest, and utility value were estimated with latent growth modeling. In the first sets of analyses, the model did not include any covariates; in the second sets of models, parent- and teacher-rated abacus ability and child gender were used as covariates of the intercept and slope. Ability self-concepts declined over time ($\beta_{slope} = -.94$, z = 9.72, $p < .05$), with an acceptable model fit ($\chi^2 = 259.56$, $df = 121$, $p < .01$ CFI= .95, TLI = .95, RMSEA = .08). The significant correlation ($\phi = -.44$, z = 2.90, $p < .05$) between the intercept and slope indicated that the higher children perceived their ability as initially, the more their ability self-concepts decreased over time. Ratings of abacus ability by parents and teachers were positively associated with children initial perceived level of ability ($\beta = .64$, z = 6.16, $p < .05$), with a significant model fit ($\chi^2 = 324.13$, $df = 178$, $p < .01$ CFI= .95, TLI = .98, RMSEA = .07).

Interest in abacus studies also decreased over time ($\beta_{slope} = -.63$, z = 7.05, $p < .05$), with a satisfactory model fit ($\chi^2 = 42.32$, $df = 22$, $p < .05$ CFI= .98, TLI = .98, RMSEA = .07). There was a significant correlation between the intercept and slope for this model ($\phi = -.39$, z = 2.64, $p < .05$). Parent and teacher ratings of children abacus ability, and gender, were not associated with children initial level of interest or how much their interest changed over time, with a model fit of $\chi^2 = 78.48$, $df = 50$, $p < .05$ CFI= .98, TLI = .98, RMSEA = .06.

Finally, students perceptions of abacus utility value and attainment value declined over time ($\beta_{slope} = -.75$, z = 6.92, $p < .05$), with a satisfactory model fit ($\chi^2 = 195.41$, $df = 115$, $p < .05$ CFI= .95, TLI = .95, RMSEA = .07). Parent- and teacher-rated abacus ability was positively associated with children initial level of utility/attainment value ($\beta = .43$, z = 2.85, $p < .05$). Boys perceived utility and attainment values as higher than did girls; this model fit the data satisfactorily ($\chi^2 = 266.83$, $df = 174$, $p < .01$ CFI= .96, TLI = .95, RMSEA = .06). In sum, value, interest and ability self-concept all declined over time, but the decline was not predicted by parental or teacher ratings of children's abacus ability.

Effects of Studying Abacus

A confirmatory factor analysis of AQ data examined children's perceptions of the influence of abacus studies on (A) cognitive abilities, (B) attitudes and motivation, and (C) academic skills and performance. The measurement model of these three constructs fit the data satisfactorily, with $\chi^2 = 227.84$, $df = 86$, $p < .01$, TLI = .95, CFI = 96, and RMSEA = .06. Table 6.3 lists the items comprising these three influence constructs, and their standardized factor loadings. The constructs were correlated at .76

(factors A and B), .91 (factors B and C), and .82 (factors A and C). A structural equation model was next estimated with the three constructs as endogenous latent variables, and grade and gender as exogenous variables. The parameter estimates showed that there were grade level main effects for perceived influences on academic abilities ($\beta = .30$, $Z = 6.19$, $p < .01$), attitudes and feelings ($\beta = .32$, $Z = 5.91$, $p < .01$), and cognitive abilities ($\beta = .35$, $Z = 7.04$, $p < .01$). There were, however, no gender effects or gender-by-grade interactions for this model. This model fit the data satisfactorily, with $\chi^2 = 281.19$, $df = 110$, $p < .01$, TLI = .94, CFI = 95, and RMSEA = .06, and showed that the higher the children's grade level, the stronger their perception was that abacus studies were influential.

Table 6.3. Factor Structure of Abacus Influences

Factor	*Item Content*	*Factor Loadings*
A. Academic Skills & Performance		
	School mathematics studies	.82
	Middle school and high school studies	.80
	Speed in school math work	.76
	Mathematics word problems	.68
	Ability to perform calculations in my mind	.57
B. Attitudes & Motivation		
	Reducing my fear of math and numbers	.51
	Enjoyment of using/thinking about numbers	.75
	Getting along with other children	.58
	Self-confidence	.76
	Ability to compete better	.60
	Ability to work with persistence & determination	.74
C. Cognitive Abilities		
	Memory ability	.74
	Understanding the meaning of money	.66
	Understanding the meaning of numbers (like 5 and 10)	.78
	Understanding the importance of calculations	.73

Mental abacus and abacus influences. To test the influence of children's belief in the existence of a mental abacus on their thinking about the influence of the abacus, a measurement model was tested for the relationship between children's belief in the mental abacus and their view of abacus influences in the cognitive, attitudinal/motivational, and academic domains. The model fit the data satisfactorily, with $\chi^2 = 263.60$, $df = 113$, $p < .001$, CFI = .98, TLI = .97, RMSEA = .05. Children's belief in the existence of a mental abacus was associated with their perceptions of abacus studies as influencing cognitive abilities ($\beta = .70$, $z = 13.58$, $p < .01$), attitudes and motivation ($\beta = .69$, $z = 11.02$, $p < .01$), and academic skills and performance ($\beta = .65$, $z = 12.35$, $p < .01$).

Mathematics vs. abacus studies: Direction of influence. On the Abacus Questionnaire, children chose from the following options the statement that best represented their viewpoint: (a) "school mathematics studies influenced abacus learning relatively more than vice versa," (b) "abacus studies influences school mathematics learning more than vice versa," (c) "there is no relationship between the two types of learning," or (d) the "influence between abacus and mathematics learning is bi-directional." The modal response was that abacus had a relatively greater influence on mathematics learning than vice versa (44.5%), followed by the view that the influence between the two domains was bi-directional (39.9%). Fewer children (8.6%) thought that mathematics studies had a relatively greater influence on abacus learning, and only 7% of students thought abacus and mathematics learning were unrelated.

Parents and teachers also listed examples of how abacus study influences children. Parents ($n = 396$) were first asked: "How do you think abacus studies influences children's overall education?" In order of frequency, parents listed "speed of calculations" ($n = 158$), "ability to do mental calculations" (63), "ability to concentrate" (51), "calculations ability" (31), "persistence" (17), "confidence in math and calculations" (15), "interest in math" (12), "accuracy in calculations" (11), "ability with times tables" (11), "endurance" (10), "ability with numbers" (5), "dexterity" (5), "interest in numbers" (4), "judgment" (4), and "competitiveness" (2 parents). When asked the same question, teachers listed the following, in order of frequency: "abacus increases liking for doing calculations in school math class," "endurance," "concentration," "sensitivity," "fundamental abilities in doing calculations," "persistence, concentration, "strong stamina," "intuition," "ability to quickly see a problem," "ability to do mental representations automatically," "competitiveness and enthusiasm", "attentiveness," "memory ability," and "interest in problem solving." Because of the small number of teachers ($n = 14$), the frequencies of these responses were small. Of the items, "sensitivity," "stamina," "intuition," "ability to quickly see a problem," "memory," and "attentiveness" were listed by teachers but not by any parents.

Mathematics vs. calculations: Two domains? To determine whether motivation constructs for the general domain of school mathematics were actually the same as the constructs for the domain of performing calculations, confirmatory factor analyses were performed on the MQ data by estimating the same measurement models for mathematics vs. calculation constructs. A model assuming two separate domains, e.g. separate mathematics and calculation indicators, was compared with a model assuming that one general construct reflected both mathematics and calculation indicators. Chi-square difference tests between the domains of school math and calculations showed that the constructs of Calculation Ability Self-Concept and Mathematics Ability Self-Concept were actually best seen as part of the same construct, χ^2_{dif} =.05, $df_{dif} = 1$, $p > .05$. But for all the other constructs, participants clearly distinguished between the mathematics vs. calculations domains, with $\chi^2_{dif} = 14.32 \sim 217.42$, $df_{dif} = 1$, $p < .05$.

Comparisons of Abacus versus Non-Abacus Students

Two-group confirmatory factor analyses were performed to test for group differences between abacus students vs. non- students, for constructs in the calculations and school mathematics domains. A baseline model was first estimated for each set of constructs, with no equality constraints on the parameters. Table 6.4 lists the standardized factor loadings and goodness of fit indices for each baseline measurement. A second model was then estimated for each set of constructs, constraining all the factor loadings to be equal. The goodness of fit index (Chi-square) showed no significant changes ($\chi^2_{dif} = 8.31$, $df_{dif} = 4$, $p > .05$) for the mathematics constructs, implying basic measurement invariance (same constructs) of the mathematics constructs between the two groups. However, the chi-square changed significantly ($\chi^2_{dif} = 23.96$, $df_{dif} = 9$, $p < .05$) for the calculation constructs, implying partial invariance of the measurement of calculation constructs. Further explorations showed that responses to two questions, "When you get something just right doing calculations, how happy do you feel?" and "How much do you worry about doing badly or having trouble with doing calculations?" had different loadings, i.e., they had different weights in measuring the constructs for the two groups. As a result, further latent mean comparisons were based on the models with invariant factor loadings.

The measurement of the Calculation and Mathematics constructs were satisfactory, with $\chi^2 = 438.97$, $df = 151$, $p < .05$, TLI = .93, CFI = .94, RMSEA = .07 for the Calculation model, and $\chi^2 = 125.91$, $df = 30$, $p < .05$, TLI = .95, CFI = .96, RMSEA = .09 for the Mathematics model. Given that the latent means were assumed to be zero for the Control Group, the abacus pupils had higher Mathematics Ability Self-Concepts ($\tau = .67$, z = 7.50, $p < .01$) and Mathematics Interest than the non-abacus Control Group ($\tau = .48$, z = 5.64, $p < .01$). The abacus pupils also had higher Calculations Ability Self-Concept ($\tau = .82$, z = 7.59, $p < .01$) and Calculations Interest ($\tau = .69$, z = 8.10, $p < .01$). But the Control Group reported higher Calculations

Table 6.4. Factor Structure of Calculation and Mathematics Constructs: Abacus versus Non-Abacus Students

		Factor loadings	
Constructs	*Item Content*	*Non-Abacus*	*Abacus*
	Calculation		
Factor 1	Are you fast at doing calculations?	.70	.64
	How well do you understand doing calculations?	.71	.62
Factor 2	Do you like doing calculations? Dislike?	.88	.83
	Is doing calculations fun? Not fun?	.94	.91
	Is doing calculations interesting? Not interesting?	.90	.87
	Do you look forward to doing calculations at school?	.84	.79
Factor 3	When you do calculations at school, how hard do you try?	.80	.71
	How hard do you work on doing calculations at home?	.71	.59
Factor 4	When you take a calculations test, how nervous do you get before the test?	.71	.43
	How much do you worry about doing badly or having trouble with doing calculations?	.50	.87
Factor 5	When you go out into society, how important will it be to do calculations?	.75	.76
	When you get something just right doing calculations, do you feel joyful?	.52	.43
	How important do you feel mathematics will be in your future life?	.61	.56
	How much will you need to be able to do calculations after you become an adult?	.67	.68
	Mathematics		
Factor 1	Is math your specialty? Weakness?	.94	.84
	Are you strong or weak at doing word problems in math?	.67	.63
Factor 2	Do you like doing math? Dislike?	.90	.85
	Is math fun? Not fun?	.91	.87
	Is math interesting? Not interesting?	.83	.81
Factor 3	How important is it to you to solve math problems?	.82	.78
	How important do you feel math will be in your future life?	.73	.69

Effort than the Abacus Group ($\tau = -.42$, $z = 4.33$, $p < .01$). There were no differences between the Control Group and Abacus Group for the following constructs: Mathematics Attainment/Utility Value ($\tau = -.02$, $z = .20$, $p > .05$), Calculations Attainment/Utility Value ($\tau = .15$, $z = 1.58$, $p > .05$), or Calculations Anxiety ($\tau = -.04$, $z = .44$, $p > .05$).

Attributions for Success and Failure

Both the AQ and MQ asked children to attribute their successes and failures to one of six causes: effort, ability, luck, task difficulty, mood, or interest. Table 6.5 presents the results of a Chi-square analysis of these data, comparing the attributions made by the Control Group and Abacus Group participants for their mathematics and calculations performance. Overall, small majorities of both the Control and Abacus Groups attributed both their failures and successes, across domains, to effort. The results also showed some different patterns of attributions between the two groups for both success and failure attributions, for both the mathematics and calculation domains. Specifically, more Abacus Group than Control Group children attributed success on mathematics and calculations tasks to their levels of interest and ability, and more Abacus than Control Group children attributed their failures at mathematics and calculations to bad luck and task difficulty levels. Finally, the Control and Abacus groups differed in relative proportions of attributions for success on tasks, but not for failures.

Additional Chi-square analyses tested whether attributions by Abacus Group children for failures and successes differed between the abacus, mathematics, and calculations domains. Table 6.6 shows the following patterns in the responses of Abacus Group pupils. First, they attributed failure more often to luck and less often to difficulty, for abacus tasks than for calculations or school mathematics tasks. Second, they more often attributed success on abacus tasks to difficulty, effort, and mood, and less often to ability, compared with school mathematics or calculations tasks. Lastly they attributed success more often to interest, in the mathematics domain than in the abacus or calculations domains.

Characteristics of Superior Abacus Students

Abacus teachers' responses to the question "What do you think are the characteristics of a superior abacus student?" included the following: works without taking a break, concentration power, competitiveness, not diverted by obstacles, enjoys solving problems, good at doing mental calculations, can conjure images, obedient, has leadership qualities. When parents were

Table 6.5. Chi-Square Analysis of Attributions for Success and Failure in Mathematics and Calculation

	Ability		*Luck*		*Interest*		*Difficulty*		*Effort*		*Mood*		*Category Comparison*	
	Non-Abacus n (%)	*Abacus n (%)*	*Non-Abacus n (%)*	*Abacus n (%)*	*Non-Abacus n (%)*	*Abaccus n (%)*	*Non-Abacus n (%)*	*Abacus n (%)*	*Non-Abacus n (%)*	*Abacus n (%)*	*Non-Abacus n (%)*	*Abacus n (%)*	$\chi^2_{(df=5)}$	*p*
Math Success	32 (9.7)	77 (17.2)*	39 (11.8)	32 (7.2)	55 (16.6)	79 (17.7)*	23 (6.9)	35 (7.8)	179 (54.1)	217 (48.5)	3 (.9)	7 (1.6)	14.32	< .05
Calculations Success	42 (12.7)	96 (21.5)*	37 (11.2)	36 (8.1)	32 (9.7)	50 (11.2)*	25 (7.6)	40 (8.9)	190 (57.4)	223 (49.9)	5 (1.5)	2 (.4)	15.53	< .05
Math Failure	24 (7.2)	35 (7.9)	19 (5.7)	47 (10.6)*	11 (3.3)	14 (3.1)	112 (33.7)	153 (34.4)*	161 (48.5)	181 (40.7)	5 (1.5)	15 (3.4)*	10.59	> .05
Calculations Failure	35 (10.5)	42 (9.4)	23 (6.9)	58 (13.0)*	12 (3.6)	10 (2.2)	96 (28.9)	140 (31.3)*	158 (47.6)	189 (42.3)	8 (2.4)	8 (1.8)	10.16	> .05

Note: Asterisks (*) indicate a significant difference between the non-Abacus Group and Abacus Group within a response category.

Table 6.6. Comparison of Attributions for Success and Failure in Abacus, Mathematics, and Calculation Studies

		Ability *n* (%)	*Luck* *n* (%)	*Interest* *n* (%)	*Difficulty* *n* (%)	*Effort* *n* (%)	*Mood* *n* (%)	$\chi^2_{(df = 5)}$	*p*
Success	Abacus	37 (8.5)	26 (6.0)	43 (9.9)	74 (17.1)	240 (55.2)	14 (3.2)	494.56	< .01
	Math	76 (17.8)	28 (6.6)	74 (17.3)	33 (7.7)	209 (48.0)	7 (1.6)	371.90	< .01
	Calculation	93 (21.8)	31 (7.3)	49 (11.5)	37 (8.5)	215 (49.4)	2 (.5)	410.26	< .01
Cochran's Q Test (df = 2)		Q = 40.54, $p < .05$*	Q = .59 $p > .05$	Q = 13.86 $p < .05$*	Q = 27.62 $p < .05$*	Q = 8.23 $p < .05$*	Q = 9.48 $p < .05$*		
Failure	Abacus	29 (6.7)	106 (24.4)	8 (1.3)	75 (17.2)	201 (46.2)	15 (3.4)	373.26	< .01
	Math	34 (8.0)	45 (10.6)	13 (3.1)	143 (33.6)	177 (41.5)	14 (3.2)	353.21	< .01
	Calculation	42 (9.7)	53 (12.4)	9 (2.1)	133 (30.6)	183 (42.1)	7 (1.6)	358.21	< .01
Cochran's Q Test (df=2)		Q = 3.74 $p > .05$	Q = 41.21 $p < .05$*	Q = 1.45 $p > .05$	Q = 39.65 $p < .05$*	Q = 5.61 $p > .05$	Q = 4.07 $p > .05$		

Note: Asterisks (*) indicate a significant difference within a response category based on Cochran's Q Test.

asked “What factors do you think influence excellent abacus students?” they cited several sources of influence with low frequency: the system of challenges to achieve higher ranks, spirit of taking on challenging goals, the examples set by teachers and parents, home environment from early childhood, native mental abilitites and ability to concentrate from early childhood, parents’ efforts and investment, efforts of teachers, amount of practice, efforts of child, ability to learn from listening to others, memory, quick judgment, and the ability to conjure up images mentally and convert images to action.

DISCUSSION

Model of Abacus Motivation

Similar to the findings of Eccles, Wigfield and others on motivation towards school mathematics in American elementary schools (e.g., Wigfield et al., 1997), our data showed a decline in motivation toward abacus learning during elementary school. We replicated the general Eccles/Wigfield model by linking the constructs of (1) ability, (2) ability self-concept, (3) interest, and (4) attainment/utility value, with data on abacus motivation. Gender differences also emerged in the perception of the value of abacus abilities (increasingly evident in upper elementary school), but age differences and changes were more notable than gender effects for perceived ability. Unfortunately, we did not collect objective performance data and could not ascertain whether our constructs predicted task choice or performance. Yet the findings are important because we showed that a model based exclusively on American data was valid in Japan for a previously unstudied domain: abacus studies.

Age Trends in Abacus Motivation

Three motivational constructs for abacus studies (value, interest and ability self-concept) all declined over time, and this decline was not predictable based on parental or teacher ratings of children’s abacus ability. The longitudinal data also showed that the stronger children perceived their ability to be initially, the more their ability self-concepts decreased over time. These declines would have been expected based on previous findings on mathematics motivation by Wigfield et al. (1997) and Jacobs et al. (2002). But at the same time as children’s value for abacus studies declined, their appreciation increased for the three types of abacus influences (cognitive, attitudinal, academic). These findings are reconcilable in that recognition of influence shows a general appreciation for abacus studies while motivational constructs reveal children's individual perceptions about themselves. It should also be noted that grade level differences and patterns of attitudes and motivation toward abacus vs. school mathematics were to some degree influenced by sample attrition. Children chose to continue in abacus studies or to terminate lessons, and abacus learners become an increasingly select sample with age.

Mental Abacus

Our data on the mental abacus consisted of opinions about the existence of a mental abacus, rather than measures of children's actual use of a mental abacus (as in Stigler et al., 1986) or speed of processing (as in Amaiwa & Hatano, 1989). Yet children's beliefs about the mental abacus may be as important as their use of it. In our opinion, a mental abacus may operate both automatically *and* consciously, and our data showed that a sizable number of children claim to use a mental abacus when they make calculations. It was interesting that reported use vs. non-use of the mental abacus predicted parent/teacher ratings of children's abacus abilities. In sum, many children believed that a mental abacus exists, and its existence may be related to children's motivation toward abacus tasks.

Influences of Abacus

Our findings reinforced Sugie and Itoh's (1991) conclusion that abacus study has an influence on attitudes toward school mathematics. The exploratory factor analysis showed that children perceived three general types of influence by abacus studies, on academic skills and performance, attitudes and motivation, and cognitive abilities. Parents and children shared the perception that abacus has various influences, reflecting their choice to enroll at *juku*. The three-factor model of abacus influence also indicated that children at higher grade levels had greater appreciation for all three types of influences. We also found that children's belief in the mental abacus mediated their perception of influences.

Relationship Between Abacus and Mathematics Studies

More abacus pupils believed either that abacus influenced school mathematics studies more than *vice versa* (44.5% vs. 8.6%), or that the influence between the two microworlds was mutual (39.9%). In free responses, the greatest numbers of parents felt that the main influences of abacus studies were on speed of calculations, ability to do mental calculations, ability to concentrate, and calculations ability. Teacher free responses were of such small frequency and thus were difficult to interpret. The free responses of teachers and parents all point to the influence of abacus studies on calculation ability. In sum, our data suggested that the two microworlds were not entirely segregated, and we agreed with Hatano (1989) that the two areas of learning probably interact. It was also notable that students clearly differentiated between the domains of school calculations and school mathematics.

Though attainment/utility values were similar between abacus students and the group of school pupils who did not study abacus, there were several notable differences between these two groups. These findings suggested that either abacus studies raise motivation for mathematics, or children who study abacus already are more motivated toward mathematics, compared with children who do not study at abacus *juku*. Specifically, abacus pupils had higher ability self-concepts and interest for both school mathematics and school calculations. Non-abacus students, on the other hand, reported higher levels of effort on school calculations than did abacus students. One explanation for this finding is that studying abacus makes a child more proficient at calculations, requiring less effort to solve a given task. This explanation should be tested under experimental conditions, but our data did suggest the possibility that abacus learning may have a positive effect on children's learning of school mathematics.

Attributions

As in Stevenson (1992) and Holloway (1988), both abacus students and non-students in our study rated effort as the primary attribution for success at school mathematics. But our results for attributions were more complicated than the general image of Japanese students as primarily concerned with effort. For example, abacus students were more likely to attribute success on mathematics and calculations tasks to interest and ability, and were also more likely to attribute failures at mathematics and calculations to luck and task difficulty. We cannot prove a causal relationship between studying abacus and attributions, but group differences were clear and abacus learning was associated with beliefs about success and failure at school mathematics and calculations. When we compared attributions for school mathematics, school calculations, and abacus calculations, attributions for success and failure depend on experiential factors and the task domain, and display wide individual differences. It seemed that children who studied abacus gain a greater degree of interest and sense of self-efficacy in their calculations abilities, and that this mentality may transfer beyond school mathematics, particularly in calculations skills. They were able to apply their positive internal and stable attributions to successes in mathematics (to ability and interest), and in protecting this sense of self-efficacy were more likely to attribute school math/calculations failures to unstable/external factors such as luck or task difficulty.

Superior Abacus Students

When parents were asked to describe superior abacus pupils, they cited the ability to work without a break, concentration, competitiveness, enjoyment of problem solving, mental calculations ability, obedience, and leadership qualities, etc. This indicated that success in abacus studies is viewed as a combination of attitude, personality, cognitive style, and general calculation abilities. Teachers attributed success at abacus to various factors, including many of the preceding listed by parents, but they also mentioned more environmental influences, including family atmosphere and the influences of teachers and parents. It would be interesting to know if these explanations were specific to success in abacus, or if the same characteristics of children were relevant to success in other task domains.

CONCLUSIONS

As the Japanese school system evolved in recent years it eliminated Saturday classes, reduced the length of the academic calendar, and simplified and reduced the amount and difficulty of material studied in elementary school. The Ministry of Education, Culture, Sports, Science, and Technology is now promoting a greater emphasis on motivating children to learn, but education still emphasizes the goal of providing children with basic skills to make the transition to abstract thinking. Emphasizing motivation over knowledge, it established a new curriculum called fundamental learning that focused on project activities. In the classroom, the acquisition of basic learning skills now is stressed, as the foundation of more abstract concepts. As children experiencing a trend toward “unhurried learning” (“yutori kyoiku” or ゆとり教育), a decline in academic skills among elementary school children has already appeared. In particular, the unhurried learning approach has been criticized because some college students of lower academic ability will be unable to keep up with their studies due to the decline of rigor in elementary education. This negative trend is relevant to the situation at various *juku*, including those that prepare children for entrance examinations, reinforce or reteach their classroom materials, or specialize in skills relevant to academic learning (abacus, English, or *kumon juku*), because these *juku* may increasingly be necessary to fill the achievement gap left by the decline in the rigor of the standard school curriculum (Ichikawa, 2002). Perhaps because juku are privately owned and not public institutions, they have not previously been subject to adequate scientific study, and the present study allowed us to consider the role of education outside the formal system of compulsory education. As such, our research points out the need to objectively study the relationship between the formal educational system and private noncompulsory forms of education.

The data suggest that children who study at abacus *juku* have different levels of motivation for mathematics and calculation skills, compared with abacus nonusers, and follow-up research should include controlled studies on the transfer of motivation and skills among children who do vs. do not study abacus. Certain goals of supplemental abacus *juku* education are similar to those of the compulsory school system, i.e., cognitive skills and motivation to learn and work hard. Yet the world of abacus *juku* is growing more and more distant from compulsory education and abacus is losing its value within Japanese society. Notwithstanding this trend, our sample of parents still wanted their children to learn abacus skills, and that they may continue to enroll their children in abacus *juku* because they see benefits beyond abacus skills *per se*, i.e., positive effects on school mathematics learning, and on broader aspects of children's development including achievement motivation, self-reliance, and ability to concentrate. Because parents continue to recognize the positive effects of abacus learning, the abacus *juku* as an institution is likely to retain its place in Japanese society.

Abacus *juku* are rare outside East Asia, yet after-school supplemental mathematics education has become increasingly common in the United States and other Western societies. In addition, the abacus is an inviting subject of study for psychologists not all children study in the abacus domain. This creates the opportunity to conduct quasi-experiments on abacus users vs. nonusers. Future research comparing children's development of abacus performance and motivation between Japanese, Chinese, Taiwanese, and others may also reveal cultural variations and similarities in abacus skill acquisition, and in the transfer value of abacus abilities and motivation.

Finally, our longitudinal data showed that abacus motivation declined in upper elementary school, just as does motivation toward many other task domains among American samples. The Eccles/Wigfield theoretical model and psychological constructs of task values and competence were applied in looking at the abacus domain and a population of Japanese children, and future abacus motivational research must include outcome measures to predict performance and choice of tasks. Abacus educators are interested in increasing the motivation of their pupils, to improve performance and also to stave off the sharp attrition in abacus *juku* attendance. We found that studying abacus at a *juku* influences one's attitudes toward school math, and that there may indeed be a mutual influence between the study of school mathematics and abacus despite the segregation of these two microworlds of study. The results should encourage not only abacus educators, but also those concerned with the study of school mathematics, because the data showed that given the right circumstances abacus learning can promote motivation toward and achievement in school mathematics.

ACKNOWLEDGMENTS

This research was funded by the League for Soroban Education of Japan, Inc., and Hirotaka Itoh of its Nagoya branch supervised the data collection. We appreciate the participation of the students, teachers, and parents of the following *juku*: Shinshiro Shuzan Gakko, Chigo Shuzan Gakkai, Horai Shuzan Gakkai, Shirazuka Shuzan Juku, Nawa Gakuen, Ishibe Shuzan Gakuen, Yokoe Shuzan Gakuen, and Tokai Shuzan Sakurai Gakuen. The students of Hanazono Elementary School and Aoyama Middle School (Handa City) are also acknowledged. We thank Paul Pintrich, Alan Wigfield, and Jacque Eccles for their encouragement.

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