EXPLORING 'WHAT JAPANESE STUDENTS FIND IMPORTANT IN MATHEMATICS LEARNING' BASED ON THE THIRD WAVE PROJECT

Yusuke Shinno[1], Chikara Kinone[2], Takuya Baba[3]

[1]Osaka Kyoiku University, [2]University of Miyazaki, [3]Hiroshima University

The present study is an ongoing survey targeting Japanese fifth and ninth grade elementary and junior high school students respectively using the framework of "The Third Wave" international comparative study. The purpose of this research report is to describe the questionnaire survey's results and analyze some similarities and differences between fifth and ninth graders from a value perspective. The main results show that there are five common factors underlying students' valuing and that fifth graders tend to value "process", "effort", "exploration", "fact", "openness" and "progress"; in contrast, ninth graders tend to value "product", "ability", "exposition", "idea", "mystery", and "control".

THE THIRD WAVE: VALUES IN MATHEMATICS EDUCATION

"The Third Wave" is a metaphor from Alvin Toffler's book published in 1980, which implies that cognition is the first wave, affect second, and value third. It is important to note that "the wave metaphor not only encapsulates the energy for change that is generated by the values approach, but it also implies the ongoing relevance of the previous two waves since waves overlap" (Seah & Wong, 2012, p. 1). Under the coordination of the project, initially, the role of values and students' valuing in mathematics learning had been assessed using qualitative data such as interviews, classroom observations, photography or videotapes. Such qualitative data analysis had been important and useful "in a research context in which values studies were relatively new, when it was not known what the scope of values were, and indeed, what they looked like" (Seah, 2013, p. 197). More recently, a new questionnaire survey was designed and validated, due to the qualitative approach's own constraints, such as "the time and skills that are needed to investigate and analyze the values respectively" (ibid., p. 197). The questionnaire survey, called 'What I Find Important (in mathematics learning)' [herein referred to as WIFI], was conceptualized in 2012, and gathered research teams from different countries such as Australia, Brazil, China, Hong Kong, Malaysia, Japan, Singapore, Sweden, Taiwan, Turkey and the United States. (e.g., Kinone *et al*., 2013; Andersson & Österling, 2013; Seah, 2013). This paper intends to investigate the Japanese part of the questionnaire survey based on the unique framework proposed in this project. Thus, there are two research questions as follows: *what Japanese students find important in mathematics learning, and how can we analyze similarities and difference between fifth grade and ninth grade students by means of the questionnaire*.

Additionally, we would like to reflect on a problematic situation related to the first and second wave in a Japanese educational context, as some other East Asian counties may have similar experiences. According to recent well-known international comparative studies, such as the TIMSS and the PISA, Japanese students' cognitive performance in mathematics has been fairly high when compared to other countries. On the other hand, Japanese students' affective performance in mathematics has been extremely low. For example, the following table shows five high cognitively performing countries and the percentages of respective students who "agree" with the statement "I like math" cited from TIMSS 2011 (cf. Mullis *et al*., 2012; NIER, 2013).

	Grade 4 (%)	Grade 8 (%)
Singapore	79.1	77.6
Korea	64.8	41.0
Hong Kong	79.6	62.7
Taiwan	62.4	44.4
Japan	65.9	39.1
TIMSS Ave.	**81.4**	**66.2**

Table 1: Affective performance in mathematics (TIMSS 2011)

There are two problematic gaps, namely the gap between cognitive and affective performance, and between elementary and junior high school students. We believe that the Third Wave project can provide a new framework to understand and/or explain such problematic phenomena in light of the values perspective, since values are "the deep affective qualities which education fosters through the school subject of mathematics" (Bishop, 1999, p. 2).

CONCEPTUAL BACKGROUND OF THE QUESTIONNAIRE STUDY

Research on values in mathematics education began with Alan Bishop's proposal of three pairs of complementary values for (western) mathematics: *rationalism* and *objectivism, control* and *progress*, as well as *mystery* and *openness* (Bishop, 1988). Regarding the term "values" as used in mathematics education, we refer to the following conceptualizations:

> There is clearly a relationship between values, beliefs and attitudes, with the literatures suggesting that values are more deep-seated and personal than attitudes, and less rationalised than beliefs. (Bishop, 2001, p. 238)

> Values are the convictions which the individual has internalised as being the things of importance and worth. They regulate the ways in which a learner utilises his/her cognitive skills and emotional dispositions to learning. (Seah, 2013, p. 193)

In a later consideration, Bishop (1998) argued that three categories of values can be encountered in the mathematics classroom: *general educational* values (e.g., *honesty*, *good behaviour*), *mathematical* values (e.g., *rationalism, openness*), and *mathematics educational* values. According to Seah (2013), data analysis by the Third Wave project group specifically identified mathematics educational values continua such as *ability* and *effort*, *wellbeing* and *hardship, process* and *product, application* and *computation,* *facts* and *ideas*, *exposition and exploration, recalling and creating*, as well as *ICT* and *pen-and-paper*.

In developing the WIFI questionnaire, "a diverse range of items that span across the three categories of values in the mathematics classroom – mathematical, mathematics educational, and general educational" were sought after (Seah, 2013, p. 197). Here it is important to note that "children responding to the questionnaire cannot be expected to relate directly to values; hence, the questions posed are about different learning activities, regarded as value indicators. […] The learning activities pictured were treated as value indicators, and the results allowed the researchers to reflect on the problem of marking a difference between a value and a value indicator" (Anderson & Österling, 2013, p. 18). Therefore, the learning activity "learning the proof" is one item in the WIFI questionnaire categorized as an indicator of the mathematical value of rationalism.

METHODOLOGY

Now, let us explain the outline of the questionnaire. The questionnaire consists of four sections. "Section A" consists of 65 questions, 64 of which utilize a five point Likert-scale to indicate the extent that the respondent finds something important in mathematics learning; the final question is for comments. Next, "section B" consists of 10 items in which respondents mark their relative valuation of the complementary values at each end of a horizontal line. Figure 1 shows part of the instructions from section B using a non-math example. A set of ten items in section B is reflective of the conception of the complementary or continua values mentioned above.

Example (non-maths):

Watching a movie ____ _✓_ ____ ____ ____ Shopping

Figure 1: Instructions from the section B (excerpt from the WIFI)

"Section C" consists of 4 items and it is "made up of four conceptualised, open-ended items which encourage respondents to write down what they themselves value, given a common scenario of the production of a magic pill the ingestion of which makes one excel at mathematics" (Seah, 2013, p. 198). Finally, "Section D" consists of questions about personal attributes such as nationality, type of school, age, gender, etc. In the present study, the targets of analysis are sections A and B, which are the main part of the WIFI questionnaire.

The questionnaire survey was conducted in different parts of Japan in 2012; seven elementary schools (605 fifth grade students) and seven junior high schools (711 ninth grade students) participated. Although the selection of schools was not random, different types of schools such as national and public from both urban and rural areas in three different prefectures (Hiroshima, Miyazaki, and Osaka) were included. In order for the teachers to understand the aim of the questionnaire survey, we visited each school and explained its purpose. The questionnaire was both distributed to and answered by participating students in their classrooms. In one case a research member was present to observe the students as they completed the questionnaire.

In describing the 64 items in section A, we scored the five choices as follows: “absolutely important” (score: 1), “important” (score: 2), “neither important nor unimportant” (score: 3), “unimportant” (score: 4), and “absolutely unimportant” (score: 5). The construct validity for section A was assessed using a Principal Factor Analysis [PFA] with a Varimax rotation, while a cut-off criterion for factor loadings of at least .35 was used in interpreting the solution. The Kaiser-Meyer-Olkin [KMO] measure of sampling adequacy and Bartlett’s Test of Sphericity [BTS] were also used for validation. As a result, KMO was more than 0.9, and the BTS was significant at 0.001, validating the questionnaire through factor analysis. In the previous study, we compared fifth (G5) and ninth grades (G9) after the extraction of a PFA with a Promax rotation, although the previous analysis was conducted in G5 and G9 data separately (Kinone *et al*., 2013). For the further analysis, in the present study we applied independent sample t-tests to the identified the subscale scores of each factor by calculating the means of the item scores included in each factor respectively.

In describing the 10 items in section B, we scored the five positions on a horizontal line in terms of the semantic differential method, which is a type of a rating scale designed to measure connotative meaning, as follows: (left side) [-2, -1, 0, +1, +2] (right side). Figure 1, for example, would receive a score of “-1”. In order to analyze the difference between G5 and G9, we applied independent sample t-tests to 10 items’ means. The present study analyzes the results of sections A and B separately, because the construction of each section has its own scoring methods. Although there may be some interrelationships between sections A and B, a more complete analysis lies outside the scope of this report, although it is one of our future tasks.

RESULTS

Exploratory factor analysis on students’ valuing

As a result of analyzing the 64 items included in section A, we accepted five interpretable factors after the extraction of principal factor analysis with a Varimax rotation: I) *Ways of understanding and problem-solving*; II) *Mathematical stories and connections*; III) *Collectivism;* IV) *Support from others*; V) *ICT*. Five factors with eigenvalues greater than one explain 45.124% of the variance, with almost 16.645% attributed to the first factor. And seven items were eliminated. Reliability analysis yielded satisfactory Cronbach’s alpha values for each of the five factors, ranging from 0.772 to 0.936, indicating an acceptable degree of internal consistency in each subscale. Although it will take an inordinate amount of space to list data about each of the five accepted factors (such as the factor loading, commonalities, etc.) as Table 2 shows, we shall show this table because of the methodological reasons and of that there are some crucially important results of for the considerations.

items	I	II	III	IV	V	Commonality
58.Knowing which formula to use	**.710**	.168	.120	.172	.007	.576
56.Knowing the steps of the solution	**.661**	.075	.026	.193	.049	.483
63.Understanding why my solution is incorrect or	**.644**	.179	.219	.244	-.028	.555
64.Remembering the work we have done	**.642**	.165	.100	.117	-.002	.463
36.Practising with lots of questions	**.636**	.074	.133	.101	-.052	.441
37.Doing a lot of mathematics work	**.636**	.227	.178	.081	-.006	.494
54.Understanding concepts/processes	**.620**	.207	.260	.149	.030	.518
59.Knowing the theoretical aspects of mathematics	**.597**	.286	.191	.102	-.004	.485
2.Problem solving	**.571**	.109	.148	.029	.018	.361
31.Verifying theorems/hypotheses	**.564**	.229	.316	.082	.042	.479
42.Working out the maths by myself	**.547**	.188	.028	.082	.022	.343
47.Using diagrams to understand maths	**.544**	.285	.195	.252	-.004	.478
62.Completing mathematics work	**.526**	.205	.236	.148	-.074	.401
43.Mathematics tests/examinations	**.507**	.159	.060	.160	-.001	.312
13.Practising how to use maths formulae	**.502**	.263	.162	.068	.025	.352
46.Me asking questions	**.494**	.114	.218	.372	.039	.445
49.Examples to help me understand	**.489**	.229	.178	.342	.112	.453
55.Shortcuts to solving a problem	**.486**	.095	.036	.174	.141	.297
50.Getting the right answer	**.434**	-.006	-.197	.058	.142	.251
32.Using mathematical words	**.423**	**.408**	.172	.110	.021	.387
33.Writing the solutions step-by-step	**.423**	**.354**	.225	.277	.059	.435
8.Learning the proofs	**.420**	.249	.413	.072	-.007	.414
51.Learning through mistakes	**.418**	.159	.191	.274	-.023	.313
26.Relationships between maths concepts	**.415**	**.383**	.288	.132	.131	.437
1.Investigations	**.412**	.338	.327	.027	.029	.393
53.Teacher use of keywords	**.411**	.279	.051	.294	.093	.344
61.Stories about mathematicians	.124	**.709**	.080	.145	.091	.554
18.Stories about recent developments in mathematics	.163	**.698**	.171	.069	.134	.566
17.Stories about mathematics	.179	**.692**	.157	.066	.122	.555
39.Looking out for maths in real life	.195	**.617**	.264	.247	.074	.555
60.Mystery of maths	.264	**.610**	.182	.154	.029	.500
40.Explaining where the rules/formulae came from	.227	**.607**	.163	.115	.088	.468
34.Outdoor mathematics activities	.080	**.603**	.199	.223	.234	.514
11.Appreciating the beauty of mathematics	.215	**.601**	.146	.064	.034	.434
21.Students posing maths problems	.206	**.474**	**.404**	.142	.106	.463
20.Mathematics puzzles	.207	**.471**	.209	.115	.259	.389
12.Connecting maths to real life	.242	**.444**	.299	.161	.017	.371
10.Relating mathematics to other subjects in school	.249	**.441**	.302	.132	.102	.375
29.Making up my own maths questions	**.386**	**.405**	.333	.102	.042	.436
52.Hands-on activities	.209	**.391**	.060	.298	.138	.308
48.Using concrete materials to understand	.242	**.377**	.111	.365	.168	.374
9.Mathematics debates	.189	.276	**.571**	.244	.066	.501
19.Explaining my solutions to the class	.211	.422	**.561**	.147	.049	.562
15.Looking for different ways to find the answer	**.424**	.268	**.538**	.015	.057	.545
7.Whole-class discussions	-.010	.283	**.526**	.346	.121	.491
30.Alternative solutions	**.449**	.317	**.492**	.057	.081	.554
16.Looking for different possible answers	**.402**	.324	**.491**	.064	.026	.513
3.Small-group discussions	.046	.213	**.430**	.301	.116	.337
44.Feedback from my teacher	**.410**	.135	.175	**.592**	.040	.569
45.Feedback from my friends	.199	.185	.232	**.585**	.098	.480
41.Teacher helping me individually	.291	.235	-.041	**.388**	.070	.298
6.Working step-by-step	**.341**	.167	.190	**.384**	.059	.331
5.Explaining by the teacher	**.376**	.090	.097	**.380**	.046	.306
35.Teacher asking us questions	.313	.292	.306	**.349**	.036	.400
23.Learning maths with the computer	.002	.191	.054	.069	**.883**	.823
24.Learning maths with the internet	.005	.226	.059	.063	**.871**	.816
25.Mathematics games	.011	.328	.156	.197	**.503**	.424
Proportion of variance(%)	16.645	12.421	6.960	5.223	3.875	
Comulative proportion(%)	16.645	29.066	36.026	41.250	45.124	

Table 2: The result of the factor analysis (Section A)

How can we conceive the above labeled factors. If we attempt to make some interpretations about factor I, students' learning activities such as knowing, understanding, solving resemble some aspects of problem-solving activities that may be seen as recent Japanese mathematics classroom culture (e.g., Shimizu, 2009). In particular, the following remarks from Stigler and Hiebert (1999) seem pertinent:

> In Japan, teachers appear to take a less active role, allowing their students to invent their own procedures for solving problems. And these problems are quite demanding, both procedurally and conceptually. Teacher, however, carefully design and orchestrate lessons so that students are likely to use procedures that have been developed recently in class. An appropriate motto for Japanese teaching would be "structured problem solving". (p. 27)

Additionally, the factor III, collectivism (in other words, social interactions) can be an essential aspect of "structured problem solving". On the other hand, there are some differences between fifth and ninth graders. By applying independent sample t-tests to the subscale scores included in the five factors in G5 and G9, statistically significance differences between them were found (the significance level was set at .05). Table 3 shows the results of such an analysis for each subscale; "G5 < G9" means that fifth graders' scores are significantly low (a high degree of importance). Interestingly, there is a strong tendency among subscales, for fifth graders to find a high degree of importance when compared to ninth graders.

Factors		**G5**	**G9**	**t-tests**
Factor 1: Ways of understanding and problem-solving	Means SD	1.61 0.45	1.79 0.59	G5 < G9 t=-5.58, df=1282
Factor 2: Mathematical stories and connections	Means SD	2.00 0.62	2.51 0.76	G5 < G9 t=-13.10, df=1284
Factor 3: Collectivism	Means SD	1.63 0.56	2.14 0.73	G5 < G9 t=-13.99, df=1301
Factor 4: Support from others	Means SD	1.70 0.55	1.89 1.66	G5 < G9 t=-5.60, df=1309
Factor 5: ICT	Means SD	2.51 0.96	2.63 0.98	G5 < G9 t=-2.23, df=1279.95

Table 3: Analysis of t-test to the item means of subscale scores (Section A)

Analysis on pairs of complementary values

In the present study, the analysis of section B is rather limited, but some crucial aspects of students' valuing are explicit in terms of their frequency distribution. As a result of an analysis of the 10 items included in section B, Table 4 shows means, SD, modes, medians in total data, as well as means and SD in G5 and G9 data respectively. Here we would like to note that the modes of items 66, 68, and 74 were respectively "-1," "2," and "-2," although other items were "0." Therefore, there is a common disposition among Japanese students to explicitly value *process*, *effort*, and *openness* over *product*, *ability*, and *mystery*. Thus, this is a possible reflection of the reality of Japanese mathematics classrooms. On the other hand, we were surprised by the data for item 72 (*recalling* vs. *creating*) because it is inconsistent with the fact that "creating" is one of the most important values in the development of mathematics education in Japan, closely related to the pedagogical notion of "mathematical thinking" or "mathematical activity" (cf. Baba *et al*., 2012).

Question items	**total**		**G5**	**G9**	**t-tests**
	Means SD	Modes Medians	Means SD	Means SD	t
66. How the answer to a problem is obtained OR What the answer to a problem is	-0.86 1.040	-1 -1	-0.95 1.035	-0.79 1.040	-2.647
67. Feeling relaxed having fun doing maths OR Hardwork needed doing maths	0 1.211	0 0	-0.06 1.209	0.05 1.212	n.s.
68. Leaving it to ability OR Putting in effort	0.77 1.163	2 1	1.00 1.133	0.57 1.153	6.831
69. Applying maths concepts OR Using a rule formula	0.11 1.033	0 0	0.13 1.077	0.10 0.995	n.s.
70. Truths facts which were discovered OR Math ideas practices used in life	0.08 1.050	0 0	0.09 1.076	0.08 1.029	n.s.
71. Someone teaching explaining to me OR Exploring maths myself peers etc	0.04 1.170	0 0	0.31 1.180	-0.20 1.108	8.041
72. Remembering maths ideas etc OR Creating maths ideas etc	-0.58 1.113	0 -1	-0.52 1.155	-0.63 1.074	n.s.
73. Telling me what a triangle is OR Letting me see concrete examples first	0.39 1.155	0 0	0.50 1.180	0.30 1.125	3.058
74. Demonstrating explaining maths to others OR keeping maths magical	-1.19 0.969	-2 -1	-1.35 0.919	-1.06 0.992	-5.479
75. Using maths to predict explain OR Using maths for development progress	-0.04 1.005	0 0	0.09 1.068	-0.16 0.933	4.463

Table 4: Data and analysis of t-tests to each item (Section B)

By applying independent sample t-tests to the means of each item for G5 and G9, statistically significant differences were found between them (the significance level was set at .05) in items 66 (*process* vs. *product*), 68 (*ability* vs. *effort*), 71 (*exposition* vs. *exploration*), 73 (*rationalism* vs. *objectivism*), 74 (*openness* vs. *mystery*), and 75 (*control* vs. *progress*). There is a tendency for fifth graders in their learning activities to value "process", "effort", "exploration", "objectivism", "openness" and "progress"; in contrast, ninth graders tend to value "product", "ability", "exposition", "rationalism", "mystery" and "control." There are no significant differences between G5 and G9 for items 67 (*wellbeing* vs. *hardship*), 69 (*application* vs. *computation*), 70 (*facts* vs. *ideas*), or 72 (*recalling* vs. *creating*). In particular, since the modes of items 69, 70, and 75 in total data were nearly 0, it would mean that both phrases (complementary values) are almost equally important to them. Although further investigation is required concerning the interrelationship between the 10 items in section B, these results imply that different mathematics classroom cultures exist in elementary and junior high schools.

References

Andersson, A., & Österling, L. (2013). Measuring immeasurable values. In A. M. Lindmeier & A. Heinze (Eds.), *Proc. 37th Conf. of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 17-24). Kiel, Germany: PME.

Baba, T., Iwasaki, I., Ueda, A., & Date, F. (2012). Values in Japanese mathematics education: their historical development. *ZDM Mathematics Education*, *44*(1), 21-32.

Bishop, A. J. (1988). *Mathematical enculturation: A cultural perspective on mathematics education.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Bishop, A, J. (1998). Culture, values and assessment in mathematics. In H. S. Park, Y. H. Choe, H. Shin, & S. H. Kim (Eds.), *Proceedings of the ICMI-East Asia Regional Conference on Mathematics Education* (Vol. 1, pp. 27-37). Seoul, Korea: Korea Society of Mathematics Education.

Bishop, A. J. (2001). Educating student teachers about values in mathematics education. In F.-L. Lin & T. L. Cooney (Eds.), *Making sense of mathematics teacher education* (pp. 233-244). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Kinone, C., Shinno, Y., Baba, T., & Barkatsas, T. (2013). International comparative study "The Third Wave" regarding values in mathematics education (2): Factor analysis on Japanese students' values in learning mathematics [in Japanese]. *Research Journal of Mathematics Education (Journal of Japan Society of Mathematical Education)*, *95*(Fall Special Issue), 105-112.

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

National Institute for Educational Policy Research (Ed.). (2013). *TIMSS 2011 Sansu Sugaku Kyoiku no Kokusai Hikaku* (TIMSS 2011 International Comparative Study) [in Japanese]. Tokyo: Akashi-Syoten.

Seah, W. T. (2011). Effective mathematics learning in two Australian primary classes: exploring the underlying values. In B. Ubuz (Ed.), *Proc. 35th Conf. of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 129-136). Ankara, Turkey: PME.

Seah, W. T. (2013). Assessing values in mathematics education. In A. M. Lindmeier & A. Heinze (Eds.), *Proc. 37th Conf. of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 193-200). Kiel, Germany: PME.

Seah, W. T., & Wong, N. Y. (2012). Thematic issue on 'Values in East Asian mathematics education – The Third Wave'. *ZDM Mathematics Education*, *44*(1), 1-2.

Shimizu, Y. (2009). Characterizing exemplary mathematics instruction in Japanese classrooms from the learner's perspective. *ZDM Mathematics Education*, *41*(3), 311-318.

Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York: Free Press.