Robotics in Education: Psychological Relationships with "Making-Artifacts," Computers, and Mathematics in Japan

Tatsuya Nomura, Atsushi Omori, Yusuke Suzuki, Hiroaki Mizohata, and Keigo Yasumura

Abstract— **In the recent situation that robotics is expected for education of technologies and sciences in Japan, it is important to consider what psychological states should be achieved in students, and understand how far the current states are from the states to be achieved, especially from the perspective of "making-artifacts" in the sense of manufacturing industries. This paper reports some case studies to explore psychological relationships between robots, "making-artifacts," computers, and mathematics in younger ages. Then, the paper discusses implications on the practices of robotics in education of technologies and sciences.**

I. Introduction

ROBOTICS is recently expected in education of technologies and sciences [1]. Through the practices of making and controlling robots, students can learn not only how to use technologies as tools for problem-solving, including computers, but also sciences as bases of the technologies and ways of understanding the world, including mathematics and physics. For this aim, many schools and universities have been attempting to design robotics courses and introduce them into their curriculums. Especially in Japan, these attempts have been paid more attention.

Japan has recently had some serious problems: the trends of the decreasing younger ages and their dislike of technologies and sciences (e.g., [2] [3]). Japan has a history that its advancement has been based on technologies. The above trends mean a decline of the national strength due to the decay of technological levels in Japan. Thus, robotics is expected to elicit younger ages' interest and enthusiasm in sciences and technologies.

In mentioning younger ages' dislike of technologies and sciences in Japan, the apprehension is directed into a decline of technological levels of "making-artifacts" in manufacturing industries ("mono-dukuri" in Japanese), which have been a basis of advancement of Japan. Robotics in education of technologies and sciences is referred to encourage younger ages' positive awareness of "making-artifacts." In other words, it may be ideal that in psychological states of younger ages, a relationship is realized that robots, "making-artifacts," technologies as tools (in particular, computers), and sciences as bases of technologies (in particular, mathematics) are organically connected, as shown in Fig. 1.

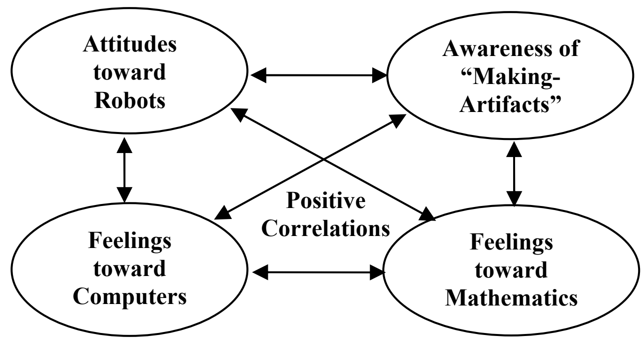

Fig. 1. An ideal relationship between robots, "making-artifacts," computers, and mathematics

However, there is no study based on psychological scales to investigate how robots, "making-artifacts," technologies, and sciences are psychologically connected in younger ages. In order to validate the effects of robotics in education of technologies and sciences, it is necessary to understand the current state on the above psychological relationship in younger ages. For this aim, the paper reports some case studies based on questionnaires.

The case studies in the paper do not deal with the effects of concrete educational programs on robotics. The subjects are university students who attended general lectures directly not related to robotics. By observing them, we can explore how far psychological states of general young people are from the above ideal state, and which personal trait affects it. Through these observation results, the paper discusses implications on the practices of robotics in education of technologies and sciences.

II. Case 1

The first case focused on the investigation of psychological relationships between robots, "making-artifacts," computers, and mathematics at a general level, and the affection of personal traits such as gender.

A. Subjects, Procedure, and Measurement

Subjects were Japanese undergraduate students at a university in the west area of Japan. They were attendees of a course of lectures about information ethics including computer security technologies, which was opened for students in higher than second grade.

A Japanese questionnaire was administered at the end of the final lecture, July 2007. The participation was voluntary.

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TABLE 1.
DETAILS OF RESPONDENTS IN CASE 1

Faculty	Male	Female
Technology related	71	15
Social Science	26	18

(Unknown: 5)

As a result, a total of 135 students responded to the questionnaire. Table 1 shows the details of the respondents based on their faculties and gender. The first case study included both students in the faculty related to technologies and those related not to technologies but social sciences. The mean age was 20.2 (*SD*: 1.7).

The questionnaire consisted of items on gender, age, affiliation, and the following four Japanese scales to measure psychological relationships between robots, "making-artifacts," computers, and mathematics:

1) Negative Attitudes toward Robots Scale (NARS): This Lickert-type scale measures human attitudes toward robots, that is, psychological states reflecting opinions that people ordinarily have about robots [4]. It consists of fourteen questionnaire items classified into three subscales: NARS1: "Negative Attitude toward Interaction with Robots" (six items), NARS2: "Negative Attitude toward the Social Influence of Robots" (five items), and NARS3: "Negative Attitude toward Emotional Interactions with Robots" (three items).

Each item is scored on a five-point scale (1: Strongly disagree, 2: Disagree, 3: Undecided, 4: Agree, 5: Strongly agree), and an individual's score on each subscale is calculated by adding the scores of all items included in the subscale, with some items reverse coded. Thus, the minimum and maximum scores are 6 and 30 for NARS1, 5 and 25 for NARS2, and 3 and 15 for NARS3, respectively. The higher score means more negative attitude toward robots.

2) Awareness of Making-Artifacts Scale (AMAS): This Lickert-type scale measures human awareness of "making-artifacts" in the sense of manufacturing industries [5]. It consists of fifteen questionnaire items of which sentences have positive meanings for "making-artifacts" including the learning of it. Each item is scored on a five-point scale (1: Strongly agree, 2: Agree, 3: Undecided, 4: Disagree, 5: Strongly disagree), and an individual's score is calculated by adding the scores of all items. Thus, the minimum and maximum scores are 15 and 75 respectively, and the higher score means more negative awareness of "making-artifacts."

3) Aikyodai's Computer Anxiety Scale (ACAS): This Lickert-type scale measures anxious emotion that prevent humans from using, learning about, and considering the meanings of using computers [6]. It consists of twenty-one questionnaire items classified into three subscales: ACAS1: "Anxiety toward Operation of Computers" (seven items), ACAS2: "Anxiety toward Approach to Computers" (seven items), and ACAS3: "Anxiety toward Social Influences of Computer Technologies" (seven items).

Each item is scored on a five-point scale (1: Strongly disagree, 2: Disagree, 3: Undecided, 4: Agree, 5: Strongly agree), and an individual's score on each subscale is calculated by adding the scores of all items included in the subscale, with some items reverse coded. Thus, the minimum and maximum scores are 7 and 35 respectively for each subscale. The higher score means stronger anxiety toward computers.

TABLE 2.
EXAMPLES OF ITEMS AND CRONBACH'S ALPHA-COEFFICIENTS OF NARS, AMAS, ACAS1, AND MARS1 IN CASE 1

	#. Items	Example of Item Sentences	α
NARS1	6	"I would feel very nervous just standing in front of a robot."	.844
NARS2	5	"I feel that if I depend on robots too much, something bad might happen."	.739
NARS3	3	"If robots had emotions, I would be able to make friends with them."*	.724
AMAS	15	"Making-artifacts is worthwhile because its fruits are clear."	.877
ACAS1	7	"I would feel anxiety if I was given a job where I had to operate computers."	.808
MARS1	18	"Entering a room where a lecture on mathematics is open,"	.946

* Reverse Coded Item

In this case study, however, Cronbach's α-coefficients of ACAS2 and ACAS3 were lower than 0.7. As a result, these subscales did not have sufficient consistency. Thus, these subscales were omitted and only ACAS1 was included in the analysis.

4) Mathematics Anxiety Rating Scale (MARS): This scale measures anxiety associated with the single area of the manipulation of numbers and the use of mathematical concepts [7]. In this case study, the Japanese version of MARS [8] was used.

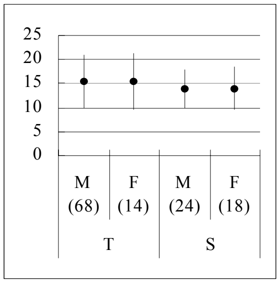
The Japanese version of MARS consists of thirty-four questionnaire items of which sentences represent situations related to learning and using mathematics. These items are classified into two subscales: MARS1: "Anxiety toward Learning Mathematics" (eighteen items), and MARS2: "Anxiety toward Evaluation on Mathematics" (sixteen items). Each item is scored on a five-point scale (From 0: I do not feel anxious at all, to 4: I feel very much anxious), and an individual's score on each subscale is calculated by adding the scores of all items included in the subscale. Thus, the minimum and maximum scores are 0 and 72 for MARS1, and 0 and 64 for MARS2, respectively. The higher score means stronger anxiety toward mathematics. This case study focused on students' motivation for learning. Thus, only MARS1 was included in the analysis.

Table 2 shows examples of the items and Cronbach's α-coefficients of the above scales in this case study.

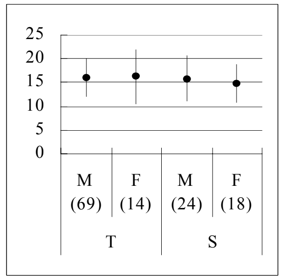
B. Results

Firstly, two-way ANOVAs were conducted to determine the effects of gender and faculties of subjects on the scale scores. Fig. 2 shows the means and standard deviations of the scale scores, and the results of the ANOVAs.

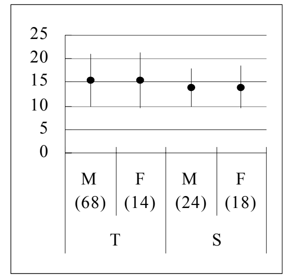
There was no statistically significant effect of gender or the faculties, or interaction effect in the NARS subscale scores.



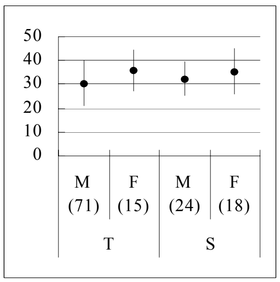
NARS1
(Gender: F = .000, *n.s.*, Faculty: F = 1.890, *n.s.*, Interaction: F = .002, *n.s.*)



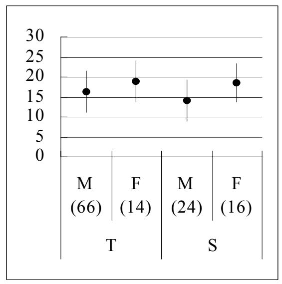
NARS2
(Gender: F = .169, *n.s.*, Faculty: F = .670, *n.s.*, Interaction: F = .515, *n.s.*)



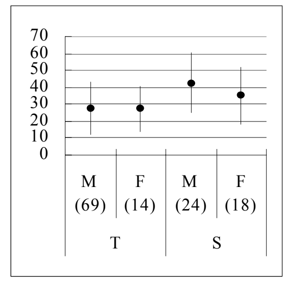
NARS3
(Gender: F = .414, *n.s.*, Faculty: F = .145, *n.s.*, Interaction: F = .001, *n.s.*)



AMAS
(Gender: F = 4.760, $p < .05$, Faculty: F = .136, *n.s.*, Interaction: F = .236, *n.s.*)



ACAS1
(Gender: F = 9.442, $p < .01$, Faculty: F = 1.370, *n.s.*, Interaction: F = .718, *n.s.*)



MARS1
(Gender: F = 1.401, *n.s.*, Faculty: F = 11.049, p < .001, Interaction: F = 1.164, *n.s.*)

Fig. 2. Means and standard deviations of NARS, AMAS, ACAS1, and MARS1 scores, and results of ANOVAs in Case 1
(M: male. F: female, T: faculty related to technologies, S: faculty related to social science, numbers in bracket: sample numbers)

There was a statistically significant difference in the AMAS scores between the male and female students although there was no effect of faculties or interaction effect. Moreover, there was a statistically significant difference in the ACAS1 scores between the male and female students although there was no effect of faculties or interaction effect. Furthermore, there was a statistically significant difference in the MASR1 scores between the students in the faculty related to technologies and those related not to technologies although there was no effect of gender or interaction effect.

Next, Pearson's correlation coefficients r were calculated between the scale scores to determine relationships between negative attitudes toward robots, negative awareness of "making-artifacts," anxiety toward operation of computers, and anxiety toward learning mathematics. Table 3 shows these coefficients based on the complete samples, the faculties, and genders.

First, there were no correlations between NARS subscales and AMAS. Although there was a weak positive correlation between NARS1 and AMAS in the samples of the faculty related to social sciences at a statistically significant trend, there was no statistically significant difference between those samples and the samples of the faculty related to technologies ($\chi^2(1) = 1.461$, *n.s.*).

Second, there was a moderate positive correlation between NARS1 and ACAS1 in the female samples at a statistically significant level and it was stronger than that in the male samples at a statistically significant trend ($\chi^2(1) = 2.929$. $p < .1$). There was no statistically significant difference between the samples of the faculty related to social sciences and those of the faculty related to technologies ($\chi^2(1) = 1.033$, *n.s.*). Moreover, there was a weak positive correlation between NARS2 and ACAS1. There were no statistically

TABLE 3.
PEARSON'S CORRELATION COEFFICIENTS BETWEEN NARS, AMAS, ACAS, AND MARS1 SCORES IN CASE 1

		ACAS1	MARS1	AMAS
NARS1	Complete samples	.232*	.163†	.063
	Technology related	.228*	.277*	.074
	Social Science	.410**	.133	.299†
	Male	.178†	.088	.034
	Female	.511***	.403*	.199
NARS2	Complete samples	.189*	.097	.080
	Technology related	.241*	.064	.073
	Social Science	.063	.227	.087
	Male	.221*	.025	.150
	Female	.216	.280	-.035
NARS3	Complete samples	.101	-.058	.049
	Technology related	.217†	.025	.028
	Social Science	-.132	-.156	.111
	Male	.101	-.086	.071
	Female	.219	.012	.072
ACAS1	Complete samples		.079	.399***
	Technology related		.255*	.442***
	Social Science		-.107	.189
	Male		.038	.461***
	Female		.242	-.007
MARS1	Complete samples			.298***
	Technology related			.286**
	Social Science			.269†
	Male			.347***
	Female			.209

(†$P < .1$, *$P < .05$, **$P < .01$, ***$P < .001$)

significant differences between the samples the faculty related to social sciences and those of the faculty related to technologies ($\chi^2(1) = .841$, *n.s.*), or between the male and female samples ($\chi^2(1) = .000$, *n.s.*). In addition, there was no correlation between NARS3 and ACAS1. However, there was a weak positive correlation in the samples of the faculty related to technologies at a statistically significant trend, and it was stronger than that in the samples of the faculty related to social sciences at a statistically significant trend ($\chi^2(1) = 3.141$, $p < .1$).

Third, there were no correlations between NARS subscales and MARS1. Although there was a weak positive correlation in the samples of the faculty related to technologies at a statistically significant level, there was no statistically significant difference between those samples and the samples of the faculty related social sciences ($\chi^2(1) = .585$, *n.s.*). Moreover, although there was a moderate positive correlation in the female samples at a statistically significant level, there was no statistically significant difference between the female and male samples ($\chi^2(1) = 2.491$, *n.s.*).

Fourth, there was a weak positive correlation between ACAS1 and MARS1 in the samples of the faculty related to technologies at a statistically significant level, and it was stronger than the samples in the faculty related to social sciences at a statistically significant trend ($\chi^2(1) = 3.290$, $p < .1$). Moreover, there was a moderate positive correlation between ACAS1 and AMAS. Although there was no statistically significant difference between the faculties ($\chi^2(1) = 2.042$, *n.s.*), the correlation in the male samples was stronger than that in the female samples at a statistically significant level ($\chi^2(1) = 5.289$, $p < .05$).

Finally, there was a moderate positive correlation between MARS1 and AMAS. There were no statistically significant differences between the faculties ($\chi^2(1) = .009$, *n.s.*) or genders ($\chi^2(1) = .501$, *n.s.*).

III. CASE 2

The results of the first case study suggested the gender difference and difference dependent on the educational backgrounds about psychological relationships between robots, "making-artifacts," computers, and mathematics. The second case study limited sampling to students related to technologies to investigate the influence of the more detailed educational background.

A. Subjects, Procedure, Measurement

Subjects were Japanese undergraduate students in the same university as the first case study. All the students were at the faculty related to technologies, and attendees of a basic course of lectures about mathematics, which was opened for students in the first grade.

A Japanese questionnaire was administered at the end of the lecture, October 2007. The participation was voluntary. As a result, a total of 185 students responded to the questionnaire (Male: 162, Female: 12, unknown: 11). This case study focused on these 162 male samples for more controlled analysis. The mean age was 19.0 (*SD*: 1.0). The affiliations of the respondents consisted of the following departments:

-- **EI**: department related to electronics and informatics ($N = 45$),

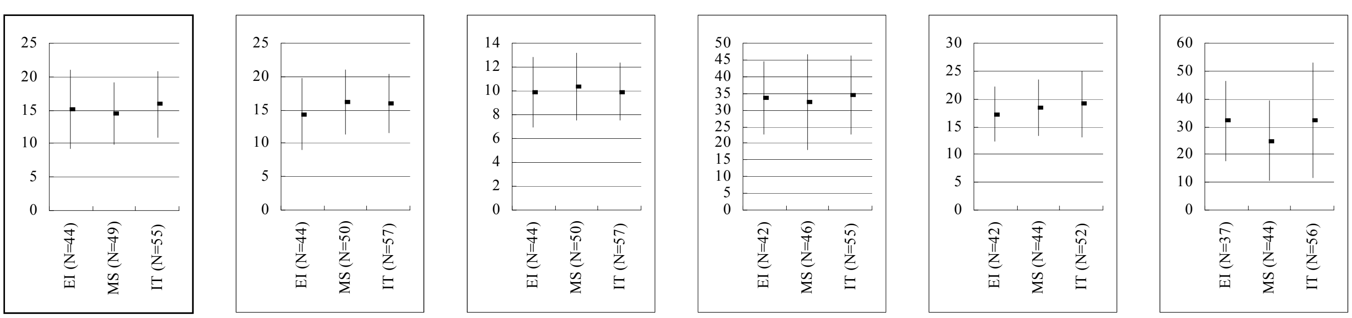
-- **MS**: department related to mechatronics and system engineering ($N = 53$),

-- **IT**: department related to information technologies ($N = 64$).

In the same way as the first case study, NARS1-3, AMAS, ACAS1, and MARS1 were used. Chronback's α-coefficients were .827 for NARS1, .832 for NARS2, .683 for NARS3, .934 for AMAS, .758 for ACAS1, and .952 for MARS1, respectively (on the 185 samples).

B. Results

Firstly, one-way ANOVAs were conducted to determine the effects of the department of the subjects on the scale scores. Fig. 3 shows the means and standard deviations of the scale scores, and the results of the ANOVAs. The results revealed no statistically significant differences between the departments, except for a statistically significant trend on MARS1.



NARS1 ($F = .864$, *n.s.*) NARS2 ($F = 1.958$, *n.s.*) NARS3 ($F = .488$, *n.s.*) AMAS ($F = .372$, *n.s.*) ACAS1 ($F = 1.401$, *n.s.*) MARS1 ($F = 2.717$, $p < .1$)

Fig. 3. Means and standard deviations of NARS, AMAS, ACAS1, and MARS1 scores, and results of ANOVAs in Case 2
(EI: the department related to electronics and informatics, MS: the department related to mechatronics and system, IT: the department of information technologies, numbers in bracket: sample numbers)

TABLE 4.
PEARSON'S CORRELATION COEFFICIENTS BETWEEN NARS, AMAS, ACAS, AND MARS1 SCORES IN CASE 2

		ACAS1	MARS1	AMAS
NARS1	Complete samples	.166†	.168†	.282***
	EI	.175	.403*	.465**
	MS	.087	.122	.331*
	IT	.200	.051	.090
NARS2	Complete samples	.164†	.028	.130
	EI	.016	.054	.067
	MS	.236	.238	.201
	IT	.196	-.062	.127
NARS3	Complete samples	-.001	-.080	-.101
	EI	-.114	-.426**	-.422**
	MS	.195	-.017	.015
	IT	-.047	.114	.070
ACAS1	Complete samples		.366***	.151†
	EI		.430**	.042
	MS		.459 **	.397**
	IT		.345*	.024
MARS1	Complete samples			.220*
	EI			.353*
	MS			.212
	IT			.172

(†$P < .1$, *$P < .05$, **$P < .01$, ***$P < .001$)

Next, Pearson's correlation coefficients r were calculated between the scale scores to determine relationships between negative attitudes toward robots, negative awareness of "making-artifacts," anxiety toward operation of computers, and anxiety toward learning mathematics. Table 4 shows these coefficients based on the complete samples, and the departments.

First, there was a weak positive correlation between NARS1 and AMAS. Although there was no statistically significant correlation only in the samples of IT, there was no statistically significant difference between the three departments ($\chi^2(2) = 3.859$, *n.s.*). Moreover, there was no correlation between NARS2 and AMAS. On the other hand, there was a statistically significant negative correlation between NARS3 and AMAS only in the samples of EI. In fact, there was a statistically significant difference between the three departments ($\chi^2(2) = 6.787$, $p < .05$).

Second, there were no statistically significant correlations between NARS subscales and ACAS1. Moreover, there were also no statistically significant correlations between NARS1 and MARS1 or NARS2 and MARS1. Although there was a moderate positive correlation between NARS1 and MARS1 only in the sample of EI at a statistically significant level, there was no statistically significant difference between the three departments ($\chi^2(2) = 3.002$, *n.s.*). On the other hand, there was a statistically significant negative correlation between NARS3 and MARS1 only in the samples of EI. In fact, there was a statistically significant difference between the three departments ($\chi^2(2) = 6.798$, $p < .05$).

Third, there was a moderate positive correlation between ACAS1 and MARS1 at a statistically significant level. There was no statistically significant difference between the three departments ($\chi^2(2) = .424$, *n.s.*). Moreover, there was no correlation between ACAS1 and AMAS. Although there was a statistically significant correlation only in the sample of MS, there was no statistically significant difference between the three departments ($\chi^2(2) = 3.936$, *n.s.*). In addition, there was a weak positive correlation between MARS1 and AMAS at a statistically significant level. Although there was a statistically significant correlation only in the sample of EI, there was no statistically significant difference between the three departments ($\chi^2(2) = .790$, *n.s.*).

IV. DISCUSSION

Fig. 4 shows the psychological relationships between robots, "making-artifacts," computers, and mathematics in the case studies.

The trend in case 1 is summarized as follows:

-- The female students had more negative awareness of "making-artifacts" and stronger anxiety toward operation of computers than the male students had.

-- The students in the faculty related to technologies had lower anxiety toward learning mathematics than those in the faculty not related to technologies.

-- There was a moderate correlation between negative awareness of "making-artifacts" and anxiety toward learning mathematics.

-- The female students had a stronger correlation between negative attitudes toward interaction with robots and anxiety toward operation of computers than the male students had.

-- The male students had a stronger correlation between

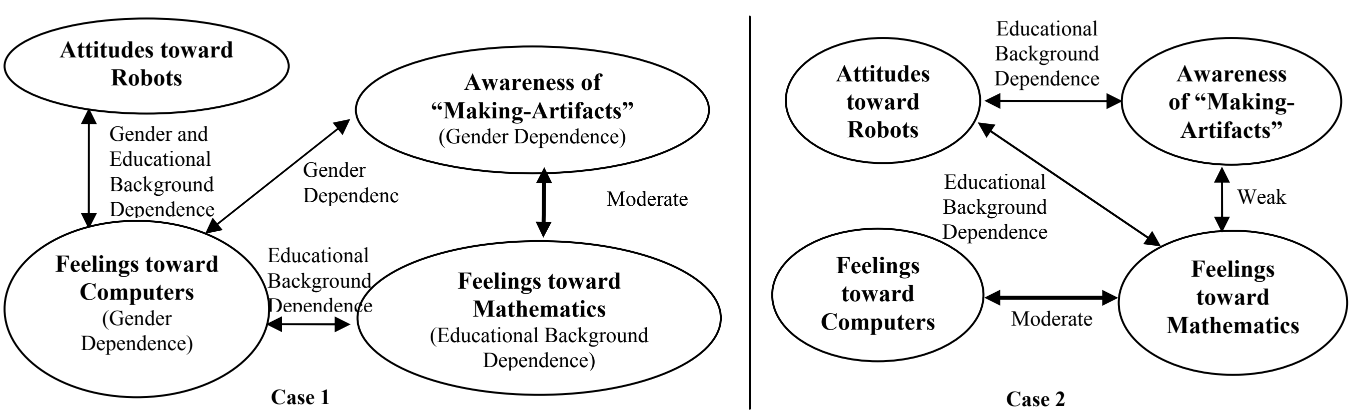


Fig. 4. Psychological relationship between robots, "making-artifacts," computers, and mathematics in the case studies

negative awareness of "making-artifacts" and anxiety toward operation of computers than the female students had.

-- The students in the faculty related to technologies had stronger relationships between negative attitudes toward emotional interaction with robots and anxiety toward operation of computers, and between anxiety toward operation of computers and anxiety toward learning mathematics, than those in the faculty not related to technologies.

The trend in case 2 is summarized as follows:

-- There were no differences between the departments in negative attitudes toward robots, negative awareness of "making-artifacts," anxiety toward operation of computers, and anxiety toward learning mathematics.

-- There was a weak positive correlation between negative attitude toward interaction with robots and negative awareness of "making-artifacts."

-- Only the students in the department related electronics and informatics had moderate negative correlation between negative attitude toward emotional interaction with robots and negative awareness of "making-artifacts", and between negative attitude toward emotional interaction with robots and anxiety toward learning mathematics.

-- There was a moderate positive correlation between anxiety toward operation of computers and anxiety toward learning mathematics.

-- There was a weak positive correlation between anxiety toward learning mathematics and negative awareness of "making-artifact."

A. Implications

The above trends in the case studies suggest that many psychological paths in the relationships between robots, "making-artifacts," computers, and mathematics are cut off or dependent on personal traits such as gender and educational backgrounds even if they exist. The practices of robotics in education of technologies and sciences should begin supposing this situation.

If a student feels no his/her own connections between robots and other constructs, the experiences of making robots may be closed within the practices and not extend his/her learning motivation to wider fields of technologies and sciences, as well as "making-artifacts." Thus, the teacher should emphasize these connections in the robotics courses. Moreover, this emphasis should be regulated according to the student's personal traits including gender and his/her educational history.

Moreover, as shown in case 2, if some students have more negative feelings or attitudes toward a specific pair of constructs and feel stronger connection between them than other students, the teacher should elicit their interests related to both the constructs in ways different from the other students. Unless it is done, their negative feeling or attitudes toward a construct may reduce their positive feeling or attitudes toward another construct even if they are elicit.

In other words, if teachers aim at elicitation of students' learning motivation for technologies and sciences through the practices of robotics, they should understand which of the relationships such as shown in Fig. 1 lacks in the students' psychological states. This lacked part may determine the design of the educational programs, for example, what social situations robots act in, which physical characteristics are taught based on mathematical equations, and which software programs are used for controlling the robots, and so on. Moreover, attitudes toward robots are influenced by types of robots [9]. Thus, it should be careful which type of robots is used in the educational programs.

B. Limitations and Future Problems

It is difficult to generalize the results of the case studies in the paper due to their limited sampling. Moreover, the psychological model shown in Fig. 1 should be originally validated by more detailed analysis method such as structure equation modeling, including more psychological constructs such as evaluation apprehension and locus of control. Thus, we should explore students' psychological states in more case studies of robotics lecture courses, in particular, the changes of the psychological states before and after the courses.

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