Analyzing the Transition of Learners' Motivation to Learn Programming

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Abstract - In this research, a model of motivation design called ARCS was used to analyze the transition of learners’ motivation to learn programming. The students were in an art and design course, and a programming environment specialized for design/art called Processing was used to teach introductory programming to the students. The questionnaire based on the ARCS model was conducted three times: early, middle, and late in the course. From the analysis of the questionnaire, it has been found that the change of the motivation from early to middle in the course was more remarkable than the change from middle to late in the course. Therefore, it was important to raise and maintain the motivation of the learners in the early stage of the course. It has also been found that the correlation between the factors in the ARCS model increased as the learning progressed. Therefore, the instructors should prepare their teaching materials in such a way that the four factors in the ARCS model are balanced.

Index Terms – ARCS model, Processing, Programming education, Motivation.

INTRODUCTION

Learners’ motivation is crucial in the programming education in which the learners are required to actively apply their knowledge [1]. Therefore, it is important to analyze the factors that affect students’ motivation to learn programming.

In the authors’ previous research, the motivation of the students in the art and digital design courses to learn programming was analyzed using the assessment standard called SIEM [2], introduced by Dohi, O. Miyakawa, and N. Konno. The relation between the motivation and the evaluation items was also analyzed using the relation structure graphs [3]-[5]. As a result of the analysis, it had been proved that the transition of the students’ motivation during programming education could be explained using the relation among the factors that affected the motivation. However, the methods for improving the factors that affected students’ motivation could not be derived, because it was difficult to find the practical ways to improve the items in the SIEM assessment standard.

In this research, a model of motivation design called ARCS [6] as well as the SIEM assessment standard has been used so that the factors of motivation could be analyzed in detail. A questionnaire for programming courses based on the ARCS model has been designed. This questionnaire as well as the questionnaire based on the SIEM assessment standard was conducted three times during the course (early, middle and late) so that the transition of the students’ motivation was analyzed.

Many of the factors and the sub-level categories in the ARCS model are more fundamental than the factors and items in the SIEM assessment standard. Therefore if the ARCS model is used, it is easier to derive remedies when the students give low scores to an item in the questionnaire. The transition of the means and variances of the factors and the sub-level items was studied because it was necessary to find out what particular actions to take at different time periods in the programming courses.

The target students in this study were in the art or digital design courses. Programming is considered to be important for those students because of the following reasons:

- Many art and digital designers use computer applications today to create their work. Therefore, if they fully understand the mechanisms of those applications and the structures of data they use, they can improve their environments for creation and make the process more efficient [7].
- There are some artistic environments in which artwork can be directly generated by programming, such as Processing [8]-[9] and Design By Numbers [10]-[11]. Therefore, if the students studied a curriculum without programming, they would miss some important means of art creation [12].

Because of the nature of the students, a programming environment specialized for design/art called Processing was used in this study. It is an Open Source programming environment initiated by C. Reas and B. Fry [9]. With this programming environment, fine artwork can be created by relatively simple codes, and therefore the students can be motivated to learn programming by viewing the visually stimulating artwork they created through programming.

PROGRAMMING EDUCATION WITH PROCESSING

The programming course with Processing was offered in Osaka University of Arts (OUA). In this course, a 90 minute-class was given six times (twice per week) to the 56 students in the class. The topics covered in the programming course are shown in Table I.

The teaching materials were designed in accordance with the ARCS model so that the students were motivated...
adequately. This model assumes that there are four factors in motivation: Attention, Relevance, Confidence, and Satisfaction. Each factor has three sub-level categories, and therefore, there are in total twelve sub-level categories. The sub-level categories of the ARCS model and the corresponding measures to comply with them are listed below.

- **Attention**
  - A.1. *Perceptual arousal*: Aesthetical satisfaction with the resulting artwork.
  - A.2. *Inquiry arousal*: Asking the students to guess the codes of artwork.
  - A.3. *Variability*: The content was changed from still images to moving images, and to the content that receives mouse input.

- **Relevance**
  - R.2. *Goal orientation*: The students are in the art and digital design course.
  - R.3. *Motive matching*: Did you have chances to select the learning methods that were suitable to you?

- **Confidence**
  - C.1. *Learning requirements*: Showing examples.
  - C.2. *Success opportunity*: Changing some parameters can make the artwork much more attractive.
  - C.3. *Personal control*: The students use their own creativity to create their original artwork.

- **Satisfaction**
  - S.1. *Natural consequence*: The students will be able to use the knowledge gained in their own work.
  - S.3. *Equity*: Encouraging the students to continue learning Processing.

The questionnaire based on the ARCS model was designed specifically for the programming course with Processing, and not for general programming courses. Each question item in the questionnaire is designed to ask if each of the twelve sub-level categories in the ARCS model is satisfied. The ARCS model and the corresponding question items are listed below. Each item is presented using a five-point Likert scale, and the student would respond by checking, (1) strongly disagree; (2) disagree; (3) neutral; (4) agree; (5) strongly agree.

- **Attention**
  - A.1: Did you feel that the visually stimulating artwork give you new and surprising incentives to learn during the programming education?
  - A.2: Did you feel that you wanted to learn more during the programming education?
  - A.3: Could you study without getting tired because there were variations in the learning content?

- **Relevance**
  - R.1: Did you feel that the learning content was familiar?
  - R.2: Did you understand the goal and the importance of the learning?
  - R.3: Did you have chances to select the learning methods that were suitable to you?

- **Confidence**
  - C.1: Is the goal you should reach clear?
  - C.2: Did you feel that you had created visually stimulating artwork?
  - C.3: Did you feel that you created visually stimulating artwork because of your efforts and ability?

- **Satisfaction**
  - S.1: Did you have occasions to use your newly acquired knowledge?
  - S.2: Were you happy when you created visually stimulating artwork?
  - S.3: Was your accomplishment fairly evaluated with a consistent standard?

The order of the question items was intentionally altered and the question items in the same factor were separated in the questionnaire so that the correlation among the items in the same factor could not be attributed to the locations of the question items in the sheet.

**I. The Questionnaire Based on the ARCS model**

The SIEM assessment standard has four factors and one group for the motivation index (MV) evaluation items. Each of these factors and the group has some evaluation items as shown in the following list, and there are in total 19 evaluation items. Each item in the SIEM assessment standard is also presented using a five-point Likert scale. The question for each evaluation item can be found in [4]. Among these items, (17) Importance and (19) Expectation are used to evaluate the MV by being multiplied together.

- **Factor 1 Class construction factor:** (1) Success opportunity, (2) Familiarity, (3) Pleasure, (4)
Comprehension, (5) Perceptual arousal, (6) Significance, and (7) Curiosity arousal.

- Factor 2 Spontaneity factor: (8) Future usefulness, (9) Improvement effort, (10) Self control, and (11) Self goal.
- Factor 3 Interaction factor: (12) Communication, (13) Positive consequence, and (14) Equity.
- Factor 4 Attendance factor: (15) Attendance enthusiasm and (16) Activation Scale.
- MV evaluation items: (17) Importance, (18) State recognition, and (19) Expectation.

**EXPERIMENTAL RESULTS AND ANALYSIS**

I. The Analysis of the ARCS Questionnaire

The students in the class were asked to fill out the questionnaire three times; early, middle, and late in the course. The numbers of the students who filled out the questionnaire were 36, 34, and 28 respectively. Among those students, 21 filled out the questionnaire all three times, and the data of those students was used for the analysis.

The transition of the mean of each factor in the ARCS model is shown in Figure 1. On one item in the horizontal axis, there are three vertical bars. They correspond to early, middle, and late stages respectively from left to right. In order to observe if there were statistically significant differences between the mean of the same factor measured at different times, the t-test was conducted, and the results are shown in Table II. In this table, if the value in a cell is greater than 1.725, it means that the mean of the corresponding factor has changed during the corresponding time period. These data have revealed that the mean had not changed significantly from early to middle and from middle to late for any of the four factors.

![Figure 1](https://via.placeholder.com/150)

**FIGURE 1**
TRANSITION OF THE MEAN OF EACH FACTOR IN THE ARCS MODEL.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Early to Middle</th>
<th>Early to Late</th>
<th>Middle to Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>0.61</td>
<td>0.59</td>
<td>0.30</td>
</tr>
<tr>
<td>Relevance</td>
<td>0.86</td>
<td>0.27</td>
<td>0.14</td>
</tr>
<tr>
<td>Confidence</td>
<td>0.22</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>0.74</td>
<td>0.84</td>
<td>0.19</td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
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<td>0.19</td>
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The transition of the mean of each sub-level category is shown in Figure 2. As before, the t-test was conducted to observe if there were statistically significant differences between the mean of the same item measured at different times, and the results are shown in Table III. In this table, the values greater than 1.725 are highlighted to indicate that the mean of the corresponding items have changed during the corresponding time period.

From these data it can be observed that the mean of A.3 (Variability) had changed (decreased) from early to middle and from early to late. This fact can be attributed to the characteristic of the students in the art course. The students in the art course are accustomed to the learning style in which the main activity is execution, and they usually work on the art using their own inspiration while they are learning in class. Therefore, there are always variations in the class activities, and the students have been continuously receiving stimulus from the activities. However, it seems that the students could not be continuously receiving stimulus in the new learning activity in which programming was used as the production tool.

![Figure 2](https://via.placeholder.com/150)

**FIGURE 2**
TRANSITION OF THE MEAN OF EACH QUESTION ITEM IN THE ARCS MODEL.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Early to Middle</th>
<th>Early to Late</th>
<th>Middle to Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>1.16</td>
<td>1.30</td>
<td>1.78</td>
</tr>
<tr>
<td>A.2</td>
<td>1.00</td>
<td>1.31</td>
<td>2.22</td>
</tr>
<tr>
<td>A.3</td>
<td>1.00</td>
<td>1.00</td>
<td>3.21</td>
</tr>
<tr>
<td>R.1</td>
<td>0.20</td>
<td>0.20</td>
<td>0.72</td>
</tr>
<tr>
<td>R.2</td>
<td>0.00</td>
<td>0.00</td>
<td>1.04</td>
</tr>
<tr>
<td>R.3</td>
<td>0.00</td>
<td>0.38</td>
<td>0.72</td>
</tr>
</tbody>
</table>

**TABLE III**

<table>
<thead>
<tr>
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On the other hand, Figure 2 and Table III reveal that the mean of R.3 (Motive matching) increased from middle to late. This fact implies that the students were becoming...
acquainted with the new method of creation during the first half of the class, and after that, they were able to select the learning methods that were suitable to them using the knowledge they had obtained. This process is similar to the one in which an art student perfects themselves in the activity of producing art through creation of art.

Table III shows that the mean of A.3 (Variability), C.3 (Personal control), and S.3 (Equity) had changed from early to middle. On the other hand, only the mean of R.3 had changed from middle to late. From this fact, it can be concluded that the change in the motivation of the students in the art course to learn programming was more prevalent in the first half of the course than the second half of the course. This result can be attributed to the fact that the way of creating art with programming is new to the students. Those students needed time to adapt to the new way of producing art, and they showed change in motivation while they were adapting to the new way. This means that it is very important to keep or raise motivation of the students in the early phase of the course. Since it is a characteristic of the students in the art course to learn through the production of art, it is important to design the first half of the course in such a way that the students can be engaged in creative art producing work.

II. The Analysis with the 3D Graphs

In the previous subsection, the motivation of the students and its transition were analyzed using statistical methods. In this subsection, the motivation and its transition will be analyzed using some 3D graphs. Each of the graphs has three axes that correspond to the three sub-level categories of a factor in the ARCS model. This representation is proposed in this study because it is difficult to explain the whole aspect of the motivation of the students and its transition if the statistical methods alone are used. It is easier to explain the transition of the motivation in detail by observing data of the students displayed on the 3D graphs. More specifically, the relation among the sub-level categories in a factor, and the transition of the state of the motivation as the learning phase progresses can be grasped if the 3D graphs are drawn.

The 3D graphs for the experiments are shown in Figure 3. In Figure 3, each row represents one factor of the ARCS model and contains three 3D graphs corresponding to early, middle, and late stage respectively from left to right. In each 3D graph, the lower left corner with two zeros is the origin, and the axis pointing toward you represents the first sub-level category, the axis pointing to the right represents the second sub-level category, and the axis pointing upward represents the third sub-level category for each factor. Each sphere in the graph represents the responses of a student to the three sub-level categories. If more than one spheres coincide, a bigger sphere is shown at that point.

In the row of Attention, the cluster of the spheres is
spread along the A.1-A.2 plane at the early stage, but it is spread along the A.2-A.3 plane at the middle stage. Therefore, the variance of A.3 (Variability) increased from early to middle. At the same time, the spheres as a whole moved downward and the mean of Variability decreased. In the row of Relevance, the cluster of the spheres moved upward along the R.3 axis, and the shape of the cluster didn’t change much from middle to late. Therefore, the mean of Motive matching increased from middle to late. The reason why it increased is considered to be that the students realized at the end of the course that they could really use programming to create artwork. In the row of Confidence, the shape of the cluster changed from early to middle. At the early stage, the spheres were concentrated in a small area along the C.2-C.3 plane, but they were spread along the same plane at the middle stage. The cluster as a whole moved downward along the C.3 axis. It is assumed that the difference among individuals increased as their learning progressed regarding Success opportunity and Personal control. For the row of Satisfaction, similar analysis as for the row of Confidence can be carried out. The main difference is that the cluster as a whole moved upward and not downward along the S.3 axis.

III. The Analysis of the ARCS and the SIEM Questionnaire Combined

The transition of the mean of each question item in the SIEM assessment standard is shown in Figure 4. This figure and also the t-test that was carried out have revealed that the means of the two MV evaluation items 17 and 19 have decreased from early to middle. Since the motivation index (MV) in the SIEM assessment standard is given by the product of item 17 and item 19, the MV decreased during the first half of the course.

The t-test between the same items at different times for the variance of the items in the ARCS model was also carried out. As a result, it has been found that the variances of R.1 (Familiarity) and R.3 (Motive matching) had changed from early to middle, and also the variances of A.3 (Variability) and R.3 had changed from early to late. On the other hand, there was no sub-level category whose variance had changed from middle to late. Therefore, the variation of the students had been more prevalent in the first half of the course than the second half of the course. From the above observation, it can be concluded that the variance of the motivation was one of the factors that decreased the MV. Therefore, the variance of the students’ motivation could be decreased and the total MV level could be increased, if the students who had low motivation in terms of the SIEM assessment standard could be selected, and be given appropriate instruction based on the characteristics of the students in the art course. For this instruction, the ARCS model would be useful in giving the specific measures for each sub-level category of the motivation model.

IV. The Learner Model for Programming Education in the Art Course

The correlation between each and every pair of the sub-level categories of the ARCS model was calculated so that the learner model of the programming education in the art course based on the ARCS model was constructed. Based on the values of correlations, the correlation structure graphs were drawn. The transition of the graphs is shown in Figure 5.

In each correlation graph in Figure 5, the four nodes correspond to the four factors in the ARCS model. The thickness of the arc between two nodes shows the correlation of the two nodes, and was evaluated in the following manner:
1. for all pairs of the sub-level categories each of which was in each node (factor in the ARCS model), the correlation coefficients are calculated,
2. the correlation coefficients greater than or equal to 0.6 were extracted,
3. the thickness of the arc was proportional to the number of those correlation coefficients (if there were not any correlation coefficients, an arc was not drawn).

In Figure 5, it can be observed that the number of arcs and the thickness of each arc increased as the course progresses. Therefore the influence of the change of each factor increased. Though the change of the motivation is prevalent in the first half of the course, the correlations among the factors tend to increase toward the end of the course. Therefore, it is necessary to give instructions and the teaching materials that comply with the four factors of the ARCS model during the middle to late phase of the course.

CONCLUSIONS

Processing programming environment was used for the programming education in the art course, and the transition of the motivation of the students was analyzed using the questionnaire based on the ARCS model as well as on the SIEM assessment standard. From this analysis, the following results have been obtained:
the mean of A.3 (Variability) had significantly changed (decreased) from early to middle and from early to late,
the change of the motivation of the students in the art course to learn programming was more prevalent in the first half of the course than the second half of the course,
in the analysis of the SIEM assessment standard, the MV had decreased during the first half of the course,
the variation of the students had been more prevalent in the first half of the course than the second half of the course.

Also, the learner model of the students in the art course has been constructed based on the ARCS motivation model. These results imply that the transition of the motivation can be analyzed by utilizing the ARCS motivation model and the SIEM assessment standard together.

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