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## MODELING LEARNING MOTIVATION OF STUDENTS BASED ON ANALYSIS OF CLASS EVALUATION QUESTIONNAIRE

### MODELOWANIE MOTYWACJI DO NAUKI U STUDENTÓW NA PODSTAWIE ANALIZY KWESTIONARIUSZA OCENY ZAJĘĆ

#### Abstract

In this paper, we present our research on modeling learning motivation of students by analyzing class evaluation questionnaires, carried out with students as respondents at the end of each term to improve the courses in future semesters. We firstly defined three elements influencing learning motivation: (1) interest, (2) usefulness in the future and (3) satisfaction. Original questionnaire enquiring about those three elements was designed and conducted in multiple classes across different school years. Next, we conducted an experiment to classify students' motivation for learning using the provided answers. The results of the experiment showed that students' learning motivation can be estimated using the three elements defined in this study.

*Keywords: Information engineering, Learner model, Class analysis, Educational technology*

#### Streszczenie

W niniejszym artykule przedstawiono badania dotyczące modelowania motywacji do nauki u studentów poprzez analizę kwestionariuszy oceny zajęć przeprowadzanych w celu poprawy jakości zajęć w następnych semestrach. Najpierw zdefiniowano trzy elementy wpływające na motywację do nauki: (1) zainteresowanie przedmiotem, (2) jego przydatność w przyszłości i (3) zadowolenie z udziału w zajęciach. Oryginalny kwestionariusz zaprojektowany w celu indukcji powyższych elementów został przeprowadzony na słuchaczach różnych kursów na przestrzeni kilku lat. Zabrane odpowiedzi posłużyły do automatycznej klasyfikacji motywacji u studentów. Wyniki pokazały, że motywacja do nauki może być oszacowana za pomocą trzech elementów określonych w niniejszym artykule.

*Słowa kluczowe: kluczowe: inżynieria informacji, model studenta, analiza zajęć, technologie edukacyjne*

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## 1. Introduction

On the authors' university, similarly to many other universities and educational institutions, one of the elements of class evaluation is conducting a questionnaire at the end of each term with students as respondents. The main goal of such questionnaires is to utilize its results to improve classes in the future. Unfortunately, often in such questionnaires the learner's perspective and learning motivation has not been sufficiently considered.

For example, by dividing students into "learners with low motivation", and "learners with high motivation", the views over the evaluated classes differ greatly. Therefore, the expectations and the satisfaction (or dissatisfaction) of the classes differ depending on the students. Although these differences between students should be considered in the questionnaires, in most cases they are not identified at all, which makes "a student" to be considered as a constant value. If in such typical questionnaires the evaluations and opinions by students of different learning motivations are mixed, it could make the results of the questionnaire less reliable and not optimally useful for further course improvement.

To solve this problem, we developed a learner's model which focuses on differences in learning motivation. In this paper, we firstly define what motivation for learning is, and indicate that it can be perceived as the will to learn the contents to be learned in the classroom. Next, we present the learner's motivation model using a combination of three specific elements that in our assumption make up the learning motivation.

The outline of the paper is as follows. Firstly, we describe other research on class evaluation questionnaires in Section 2. Next, we describe Quantitative Learner's Motivation Model (QLMM) in Section 3. Furthermore, in Section 4 we describe the questionnaire design based on QLMM and describe the learning motivation prediction procedure Using QLMM. We present the evaluation experiments of the proposed model in Section 5. The results are discussed and explained in detail in Section 6. Finally, in Section 7 we conclude the paper and propose some of the ideas for future improvement of the method.

## 2. Related Research

There has been a number of research on class evaluation questionnaires. For example, Abe et al. [1] examined relations between questionnaire results and respondents' grades, and analyzed which questionnaire items are most important to obtain sufficient results. They used the multiple regression analysis and factor criteria for selection to evaluate the questionnaires' result and the respondent's grades. As for the results of the analysis, they found out that three items of the questionnaire had the most significant impact on performance, namely, "Interest in the course", "Understanding of the syllabus" and "Enthusiasm of teachers."

In other research Inayoshi and Shibata [2] performed principal component analysis using questionnaire results and attempted to extract a learner's characteristics. They discussed the problems occurring with class evaluation when the characteristics of learners is not considered in the evaluation.

In other research Itabashi [3] has analyzed a learner's learning time outside the class. He revealed that students spent more time on language classes and studying specialized subject

classes than they did other classes. On the other hand, Itabashi pointed out the limitations of analyzing the aggregated results of the questionnaire.

Keller [4, 5] proposed the ARCS model designed to stimulate the motivation of learners. The model describes the motivation of learners by applying four perspectives: “attention”, “relevance”, “confidence”, and “satisfaction.” However, since the ARCS model is a qualitative learner model, it is difficult to quantify the degree and the change in motivation.

In this study, we propose a new model to quantify learning motivation. In the proposed model, motivation is assumed to consist of three elements, which we quantify to represent the motivation of learners. Each element is quantified by carrying out the questionnaire and analyzing the overall result. Moreover, we conduct the questionnaire at the beginning and at the end of the course based on the idea that learning motivation changes with the progress of the class material and we considered the transition by comparing the quantified motivation at each time point.

### 3. Quantitative Learner’s Motivation Model (QLMM)

We developed a Quantitative Lerner’s Motivation Model (QLMM). It is composed of three basic elements representing the attitude of students towards the attended courses. Furthermore, quantification of these elements represents the general level of learning motivation in students.

In QLMM, learning motivation is regarded as “the will to learn the contents provided in the class”. To calculate it we consider the following three elements: (1) interest, (2) usefulness in the future, and (3) satisfaction. We represent learning motivation with a combination of these three elements. Each element corresponds to the points of view included in the ARCS model. Figure 1 shows the relationship between the QLMM and ARCS models.

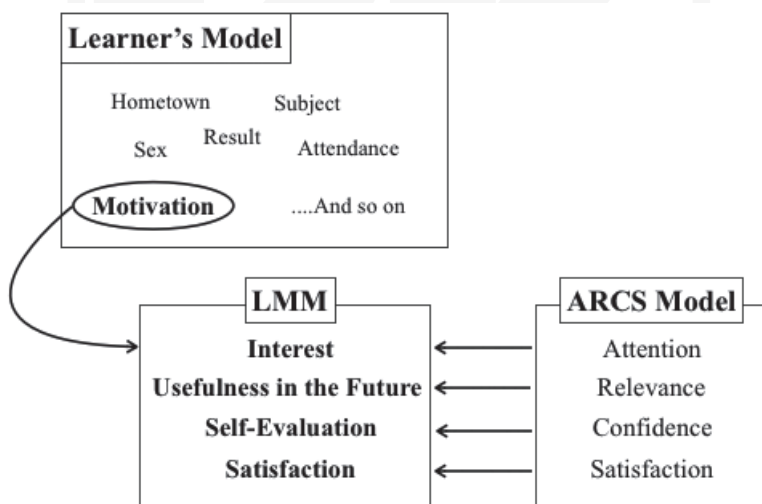


Fig. 1. Relationship of QLMM and ARCS Model

Below we describe in detail each of the three basic elements.

1. **Interest** contains elements reflecting the generally perceived interest and attention paid by the learners to the contents of the course and corresponds to the “attention” in ARCS model;
2. **Usefulness in the future** represents the elements reflecting the potential to contribute to the improvement of the skills and knowledge possessed by the learners themselves and corresponds to the “relevance” in the ARCS model;
3. **Satisfaction** contains the elements reflecting the expectations toward the class at the beginning of the course or the satisfaction of the course at the end of the school year and corresponds to the “satisfaction” in the ARCS model.

#### 4. Questionnaire Design Based on QLMM

We designed an original questionnaire for the purpose of estimation of learning motivation in students. The designed questionnaire consists of ten questions, including both choice-, and free answer-questions. All questions inquire about four elements: (1) interest, (2) usefulness in the future, (3) satisfaction, and (4) self-evaluation on the basis of the ARCS model, as described in the previous section. Figure 2 shows several questions from the questionnaire carried out at the end of the school year. Furthermore, the answers in the questionnaire designed as choice fields (with a 5-point scale), were designed to help us deal with quantification of each of the elements forming in our assumption the concept of learning motivation.

- (1) Did you have an interest in this course?
  - (2) Do you think participating in this course will help in the future (further college life or job hunting)?
  - (3) Were you satisfied with this course?
  - (4) Did you attend this course with a desire to learn?

Fig. 2. Questionnaire examples from the questionnaire

Next, to verify the accuracy of the estimation results we applied the term of “Self-confidence” (or shortly “Confidence”) from the ARCS model. Confidence gives the learner the opportunity to self-evaluate himself or herself and is calculated on the basis of the reply to the question (4) which inquires about the learner’s self-evaluation and motivation for learning.

In addition, we conducted similar questionnaires at the beginning and at the end of the course based on the assumption that learning motivation changes with the progress of class material and consider the transition by comparing the quantified motivation at each time point.

Next, we performed an experiment to predict the motivation of learners by using the answers to the four questions shown in Figure 2. The prediction was made for the answers collected from the questionnaire performed at the end of the school year. The

experiment was performed according the following procedure. Assume that questionnaire  $Q = \{q_1, q_2, q_p, \dots, q_m\}$  consists of  $m$  questions. The  $Q$  is then applied to a learner group  $X = \{x_1, x_2, \dots, x_p, \dots, x_n\}$  containing  $n$  number of persons.

**Step 1.** Firstly, the values of evaluation  $r_{i,j}$  from the answers of learners  $x_j$  for the questionnaire  $q_i$  are collected and for each question mean average  $\mu_i$  and standard deviation  $\sigma_i$  of the respondents are calculated. In this case,  $\mu_i$  is calculated according to equation (1), and  $\sigma_i$  is calculated according to equation (2).

$$\mu_i = \frac{1}{n} \sum_{j=1}^n r_{i,j} \quad (1)$$

$$\sigma_i^2 = \frac{1}{n-1} \sum_{i=1}^n r_{i,j} - \mu_i \quad (2)$$

**Step 2.** Next, classify  $r_{i,j}$  for each of the three evaluated items using as threshold  $\sigma_p$ , as in equation (3) and produce scores for all elements  $s_{i,j}$ . Next, calculate the scores  $s_{i,j}$  of each learner  $x_i$  for each question  $i$  times. Finally, sum the  $s_{i,j}$  for each learner and predict the learner's motivation  $M_j$  according to equation (4).

$$s_{i,j} = \begin{cases} 1 & \text{if } r_{i,j} \geq \mu_i \pm \sigma_i \\ -1 & \text{if } r_{i,j} \leq \mu_i \pm \sigma_i \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

$$M_j = \sum_{i=1}^m s_{i,j} \quad (4)$$

**Step 3.**  $M_j$  obtained in Step 2 has the following properties:  $\{M_j | M_j \leq |m|, M_j \in \mathbb{Z}\}$ . Therefore, we classify the learning motivation  $M_j$  into three classes according to equation (5).

$$\text{Learner's motivation is } \begin{cases} \text{high} & \text{if } M_j \geq 1 \\ \text{low} & \text{if } M_j \leq -1 \\ \text{neither high nor low} & \text{otherwise} \end{cases} \quad (5)$$

### Calculation Example

If we predict learner's motivation when the number of questions is three ( $m = 3$ ) for five learners ( $i = 5$ ),  $Q$  is represented as  $Q = \{q_1, q_2, q_3\}$  and  $X$  is represented as  $X = \{x_1, x_2, x_3, x_4, x_5\}$ . Next, if we obtain the values for evaluated items for each learner  $\{r_{1,j}, r_{2,j}, r_{3,j}\} = \{(5, 1, 4, 3, 4), (5, 1, 4, 2, 3), (4, 2, 3, 1, 2)\}$ , the mean average  $\{\mu_1, \mu_2, \mu_3\} = \{3.4, 3.0, 2.4\}$ , and  $\{\sigma_1, \sigma_2, \sigma_3\} = \{1.52, 1.58, 1.14\}$ . In this case, learner  $x_1$  obtains  $\{s_{1,1}, s_{1,2}, s_{1,3}\} = \{1, 1, 1\}$  according to equation (3) and  $M_1 = 3$ . This prediction indicates that the learning motivation in this learner is "high".

## 5. Evaluation of Proposed Model

To evaluate the proposed model we carried out a questionnaire according to the design described in Section 4, using as input attendees of multiple courses available on the authors' university. In particular, we conducted the questionnaire for nine courses, which included both the compulsory and elective courses offered to undergraduates of 1st to 3rd year. We broadened the span of undergraduates' school years (not limiting the study to only one year), and analyzed them separately on purpose – to investigate whether or not there is a difference of learning motivation in learners depending on the stage of their university career (school year) and the level of importance of the course (whether the course is elective or compulsory). In addition, we conducted the questionnaire at the beginning and at the end of the course to test the assumption that learning motivation changes with the progress of class material, and investigated the transition of learning motivation by comparing its quantified results at each time point. As a result, we obtained a total of 5,040 answers including those performed at the beginning and at the end of the school year.

Next, we performed automated prediction of learners' motivation according to the procedure described in Section 4. Finally we performed the evaluation in order to verify the validity of the predicted learners' motivation. In the experiment, we verified the validity of the predicted results using the scores of question (4) from the questionnaire (see Fig. 2), which inquires about the learner's self-evaluation regarding the learning motivation.

As evaluation criteria we used standard Precision (P), Recall (R) and balanced F-measure (F) calculated according to the equations (6), (7) and (8).

The Precision is the percentage which matches self-evaluation and the result of prediction with the three elements. The Recall is the percentage which matches self-evaluation and the result of prediction with the three elements. F-measure is a harmonic average of Precision and Recall, and is an index which represents the performance of the evaluated item.

$$P = \frac{n}{A} \quad (6)$$

*n*: Number of predictions based on three elements matching self-evaluation

*A*: Number of all responses predicted using three elements

$$R = \frac{n}{B} \quad (7)$$

*n*: Number of predictions based on three elements matching self-evaluation

*B*: Number of all responses inferred by self-evaluation of learners

$$F = \frac{2 * P * R}{P + R} \quad (8)$$

Table 1 shows the results of evaluation.

Table 1

### Evaluation results

Learner's Motivation	Precision	Recall	F-measure
Low Motivation	0.45±0.22 S.D	0.88±0.12 S.D	0.57±0.20 S.D
Neither	0.96±0.05 S.D.	0.58±0.20 S.D	0.70±0.16 S.D
High Motivation	0.44±0.16	0.89±0.15 S.D	0.57±0.17 S.D
Average	0.62	0.78	0.61

As a result of the evaluation, Precision of prediction was 0.62. Recall was 0.78. F-measure was 0.61. Therefore, we can say that the obtained results were promising. Next, we performed Fisher's exact test to verify statistical significance of the validity of the prediction results and self-evaluations, by creating a 3\*3 contingency table. As a result, the statistical significance value was  $p = 3.61e-57$ , which by standard criteria means that the results were extremely significant ( $p < 0.001$ ). This indicates that the classification based on the proposed definition of learner's motivation (QLMM) and the self-evaluation are significantly correlated.

## 6. Discussion

As the results of evaluation experiment, F-measure for the prediction of learner's motivation as "neither high nor low" was 0.70, while F-measure for the prediction of learner's motivation as either "high" or "low" was 0.57. Therefore, it was easier to accurately predict "Neither high nor low" comparing to other classes. However, performance of the prediction that "the learner has high motivation" was slightly better than the performance of predicting that "the learner has low motivation". We examined in detail the responses classified as "Neither high nor low". The comparison of quantified results with free answers revealed that in some cases although the number selected by a learner indicated to "neither high nor low" motivation, the free answer contained expressions suggesting that the learner is in fact biased to one of the sides. This confusion in the self-evaluation questions indicates that in some of the learners perception of numerical values is subjective.

To solve this problem we need to perform a similar experiment to subdivide the classes primarily set for prediction. In particular, we consider adding two classes which would refer to the cases where "the learner has slightly high motivation" and "the learner has slightly low motivation", and conduct the experiments for five classes.

Next, when we add the score of each question and predict a learner's motivation, we need to further re-examine the combination of scores for each classified item. The probable combinations of scores for each classification is represented in Figure 3. By the combination of the five categories the possible score is triplicated. For example, in the case of Combination 1 when the score is from the span  $\{-3, -2\}$ , we can predict that "the learner has low motivation". Similarly, when the score is  $\{-1\}$ , we can predict that "the learner has slightly low motivation". Take score equal to  $\{0\}$ , allows predicting that "the learner has

neither high nor low learning motivation”. The score of {1}, would indicate that “the learner has slightly high motivation”. Finally when the score is from the span {2, 3}, we can predict that “the learner has high motivation”.

After obtaining applicable results we will verify experimentally the optimal combination.

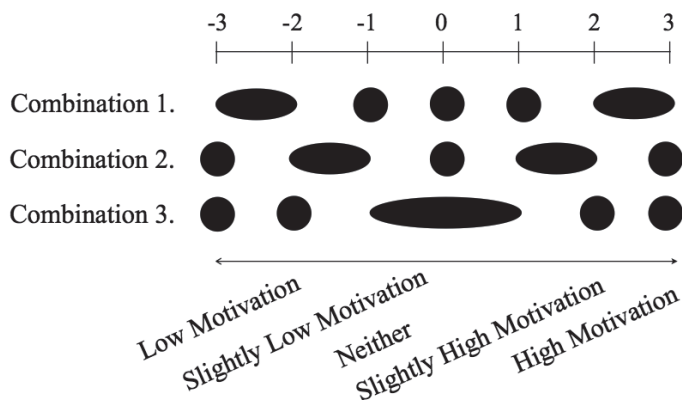


Fig. 3. Possible combinations of scores applicable for different classes

## 7. Conclusions

In this study we proposed an original Quantitative Lerner’s Motivation Model (QLMM) based on the ARCS model (Keller 1987, 1988). Next, we designed an original questionnaire to investigate the learning motivation of students. We conducted the designed questionnaire in multiple classes across different school years, and repeated the study for several years. To classify students’ learning motivation we used the answers obtained from the questionnaire and applied Fisher’s exact test as the evaluation measure. The results of the experiment showed that students’ learning motivation can be estimated using the three elements defined in this study, namely “interest”, “usefulness in the future”, and “satisfaction”.

In the future, we plan to increase the number of classes applied in the classification from the present three to five in order to further improve the classification performance. We will also re-examine the scores depending on different combinations of classes applied in the classification process.

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