# SELF-ORGANIZING MAP ANALYSIS OF EDUCATIONAL SKILLS USING QUESTIONNAIRE TO UNIVERSITY STUDENTS IN COMPUTING CLASSES

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**ABSTRACT**

We propose developing a method to set key educational skills which students need to achieve for each class using a student self-assessment questionnaire in analytical approach. It is difficult to set key academic skills for class since there are little systematic methods to set them. The questionnaire survey with 25 educational skills was conducted to ICT classes in our university using a computer-assisted web-interviewing (CAWI) technique. The questionnaire results are analyzed using self-organizing maps (SOMs). A SOM is used to visualize the similarity relations between educational skills based on student's consciousness. We show that 25 skills were classified into several skill groups of introduction, fundamentals, and advanced courses, respectively.

**KEYWORDS**

Educational Skills, Self-Organizing Map, Questionnaire Survey, Educational Performance Indicator

## 1. INTRODUCTION

The skills and attributes to be learned in school education are changing in the 21st century. There are various skills and attributes such as the 21st century skills announced by the United States Department of Education and the key competencies of the DeSeCo project organized by the OECD. Skill and attribute targets including the curricula of various countries are classified into the following three categories. The first is "basic literacy" dealing with languages, mathematics and information, the second is "cognitive skills" dealing with thinking ability and learning way, and the third is "social skills" related to society, relationships with others and independence. In Japan, the National Institute for Educational Policy Research conducted research on curriculum which fostered attributes and skills. This institute conducted integrated and experimental study of educational goals, contents, method and evaluation. In future, it is necessary to advance research on learning method, teaching method and the evaluations.

Tokai University to which we belong has formulated the following four key abilities as a specific evaluation indicator and training for cultivating social practical power since 2009. The first is thinking ability, the second is communication ability with others, the third is challenging ability and the fourth is accomplishment ability. The faculty has denoted the appropriate abilities and evaluation indicators in a syllabus as a skill to train in class. However, the skill setting method is not theoretical or systematic approach. The purpose of this study is to set effective educational skills and educational performance indicators for each class in analytical way.

As a research to evaluate evaluation indexes and skills, there are meta-analyses (Robinson, et al, 2008; Poropat, 2009; Stajkovic and Luthans, 1998), data envelopment analyses (Avkrian, 2001; Abbott, 2003), and mediational analysis (Elliot, 1999). The meta-analyses examined the relative impact of different types of leadership on students' academic and nonacademic outcomes (Robinson, 2008), and the analyses examined the relationship between self-efficacy work-related performance (Stajkovic, 1998). Poropat (2009) reported a meta-analysis of personality-academic performance relationship with cumulative sample sizes ranging to over 70,000. The data envelopment analyses examined the relative efficiency of Australian universities (Avkrian, 2001) and estimated technical and scale efficiency for the population of Australian universities

(Abbott, 2003). The study (Elliot, 1999) examined achievement goals, motivational study strategies and exam performance by a mediational analysis.

We have examined the relationship between students' educational skills using a multidimensional scaling (Taniguchi, 2018). The multidimensional scaling (MDS) is a method of multivariate analysis. It is a method of summarizing the relationships of classification objects in a low dimensional space and visualizing the relation of classification objects. Cano (2002) informed an evaluation of Spanish educational research journals using multidimensional scaling. Pounder (2009) studied an evaluating the relevance of quality to institutional performance assessment. Gatewood (1993) studied the relationship between initial job choice decisions, the corporate images and recruitment images by multidimensional scaling. However, MDS solutions require a high dimensional space to explain the relevance of complicated data.

In this study we survey the self-assessment questionnaire of students' educational skills using a self-organizing map (SOM). SOM (Kohonen, 1995) is an unsupervised neural network method. It is suitable for analyzing complicated data and its calculation is not difficult. The SOM is an efficient tool for visualizing the relationship between multidimensional data. A SOM was used to visualize the similarity relations between educational skills based on student's consciousness.

# 2. METHODS

## 2.1 Participants

A questionnaire survey was conducted in the beginning classes of the spring semester in 2018. A questionnaire for students of 19 ICT classes and 13 faculties was surveyed in Tokai University. The classes are classified by difficulty for introduction course, fundamentals course, and advanced course. Students can take these ICT classes regardless of student years or their faculties. Table 1 shows the student years, the genders, the faculties of survey respondents. All participants agreed to participate in the study. A cumulative total of 946 students participated in this study. Table 3 shows the list of ICT class names and the number of students.

Table 1. Survey respondents and legend of symbols in Figures 1 to 3

| | | Symbol | Introduction | Fundamentals | Advanced |
|---|---|---|---|---|---|
| Total | | | 578 | 273 | 95 |
| Year | First | 1 | 108 | 33 | 0 |
| | Second | 2 | 166 | 100 | 6 |
| | Third | 3 | 207 | 93 | 49 |
| | Fourth | 4 | 97 | 47 | 40 |
| Gender | Female | F | 85 | 58 | 8 |
| | Male | M | 493 | 215 | 87 |
| Faculty | Letters | LT | 49 | 41 | 3 |
| | Cultural and Social Studies | C | 7 | 2 | 0 |
| | Political Science and Economics | P | 69 | 28 | 5 |
| | Law | L | 22 | 13 | 2 |
| | Humanities and Culture | HC | 13 | 9 | 1 |
| | Physical Education | G | 20 | 6 | 1 |
| | Health Studies | H | 2 | 2 | 0 |
| | Science | S | 74 | 22 | 24 |
| | Information Science and Technology | I | 99 | 43 | 28 |
| | Engineering | E | 220 | 104 | 31 |
| | Tourism | T | 1 | 2 | 0 |
| | Information and Telecommunication | IT | 1 | 1 | 0 |
| | Biological Science | B | 1 | 0 | 0 |

Table 2. Educational skills and the abbreviations

| Educational skill | Abbr. |
|---|---|
| Learning skills | LRN |
| Thinking skills | THK |
| Inquiring skills | INQ |
| Communication skills | COM |
| Collaboration skills | CLB |
| Relationship building skills | RB |
| Self-assessment skills | SA |
| Evaluating other skills | EO |
| Problem finding skills | FND |
| Problem setting skills | SET |
| Creative thinking skills | CT |
| Planning skills | PLN |
| Implementing skills | IMP |
| Continuity skills | CNT |
| Accomplishment skills | ACP |
| Analytical skills | ANL |
| Modifying and improvement skills | MAI |
| Collecting information skills | CI |
| Decision making skills | DM |
| Logical thinking skills | LT |
| Problem solving skills | SLV |
| Artistic skills | ART |
| Setting goals skills | SG |
| Constructing knowledge skills | CK |

Table 3. ICT classes and the number of students

| ICT Class | Abbr. | Course | students |
|---|---|---|---|
| Introduction to ICT | IT | Introduction | 180 |
| Information Systems B | B | Introduction | 80 |
| Introduction to Internet Technology | N | Introduction | 45 |
| Introduction to Computer Programming | P | Introduction | 42 |
| Basic Computer Programming | BP | Introduction | 102 |
| Introduction to Web Creation | W | Introduction | 9 |
| Introduction to Data Analysis | DA | Introduction | 64 |
| Interface Design | BD | Introduction | 81 |
| Digital Imaging | DI | Fundamentals | 18 |
| Applied Computer Programming | AP | Fundamentals | 121 |
| Basic Web Creation | BW | Fundamentals | 56 |
| Music Creation | M | Fundamentals | 31 |
| Movie Creation | MV | Fundamentals | 18 |
| Computer Networking | NW | Fundamentals | 4 |
| Applied Web Creation | AW | Advanced | 2 |
| Computer Algorithm | A | Advanced | 40 |
| Computer Graphics | G | Advanced | 19 |
| Software Engineering | SE | Advanced | 3 |
| Operating System | O | Advanced | 31 |

## 2.2 Procedure

A computer-assisted web-interviewing (CAWI) technique was used to collect questionnaire data. Participants were asked to complete the online questionnaire containing the educational skills. The questionnaire and the study purpose information were provided for the participants by web pages. All participants joined voluntarily and checked the informed consent terms on the web pages.

## 2.3 Questionnaire

A questionnaire survey was conducted to analyze the 25 educational skills (Ota, 2016; Miyaji, 2011) in Table 2 that students gained through their lessons. Students declared the educational skills themselves by the questionnaire. All items are rated on a nine-point Likert-type scale from 1 (not at all) to 9 (very high degree).

## 2.4 Data Analysis

A SOM is an efficient tool for visualization of multidimensional data. The SOM was used to visualize the similarity relations between educational skills based on student's consciousness. We analyze the relations of 25 educational skills, regarding introduction, fundamentals, and advanced courses. In this analysis, 25 educational skills (Table 2) were used as SOM variables. This study used the SOM-Toolbox (Vesanto, 1999) in MATLAB to make and visualize the SOM for datasets. Questionnaire results for introduction, fundamentals, and advanced courses were used as the data sets. These data were normalized such that each variable has unit variance. After the SOMs were initialized and trained by principal component analysis, the SOM results were obtained.

## 3. RESULT

The visualization results of the SOM are shown in Figures 1 to 3. There are the U-matrices (unified distance matrices) and the label matrices in the upper low of these figures. The other matrices are the component planes. In the U-matrices, the difference of reference vectors (yellow dot sequence) represents the cluster boundary. Each label matrix illustrates the relationship among student years, genders, ICT classes, and faculties, respectively. The label matrices (year, gender, class, and faculty of students) are associated with map units. The component planes illustrate 25 educational skills as SOM variables. In the component planes, yellow means higher skill rating and blue color means lower skill rating. Similar component planes are boxed in these figures then the planes can be classified into four or six educational skill groups.

## 4. DISCUSSION

The U-matrix of Figure 1 shows two cluster boundaries in the introduction course. The left-top boundary means students have lower educational skill values by self-evaluation and the bottom-center one means they have higher skill values by themselves. Therefore the students at the left-top had lower evaluation for many educational skills and the students at the bottom-center one had higher evaluation for many skills. The U-matrix of Figure 2 shows two cluster boundaries in the fundamentals course. The left-top boundary means students have lower educational skill values by self-evaluation and the bottom-right one means they have higher skill values by themselves. As in the introduction course, the students at the left-top had lower evaluation for many educational skills and the students at the bottom-right one had higher evaluation for many skills. The U-matrix of Figure 3 shows one cluster boundary in the advanced course. The left-top boundary means students have lower educational skill values by self-evaluation. However there is no clear boundary at the bottom. As in the above two courses, the students at the top had lower evaluation for many educational skills. Regarding educational skills, students with high ratings are placed at the bottom-left or at the bottom-right.

The label matrices in Figures 1 to 3 show the educational skill values by self-evaluation does not depend on student years, genders, ICT classes, and faculties. Therefore students' consciousness of 25 educational skills does not depend on these variables.

From Figure 1, the component planes can be classified into four educational groups. Groups 11 to 41 are basic thinking skills, executing skills, communication skills, and creative skills, respectively. In most component planes, the skill evaluation is lower at the top and the evaluation is higher at the bottom. The evaluation values in group 31 are increasing from the left-top to the right-bottom. Meanwhile, the evaluation values in group 41 are increasing from the right-top to the left-bottom. Therefore, communication skills (group 31) are incompatible with creative skills (group 41) under students' consciousness. From Figure 2, the component planes can be also classified into four educational groups. Groups 12 to 42 are basic thinking skills, executing skills, creative skills, and communication skills, respectively. In most component planes, the distributions of skill evaluations in Figure 2 are the same as Figure 1. The evaluation values in groups 12 and 42 are increasing from the left-top to the right-bottom. Meanwhile, the evaluation values in groups 22 and 32 are increasing from the right-top to the left-bottom. Therefore, communication skills (group 42) and basic thinking skills (group 12) are incompatible with creative skills (group 32) and executing skills (group 22) under students' consciousness. The component planes in Figure 3 can be classified into six educational groups. Groups 13 to 63 are learning skills, thinking skills, problem finding skills, accomplishment skills, communication skills, and creative skills, respectively. For advanced course, there are three increasing directions in the component planes. One group is increasing from the right-top to the left-bottom. The appropriate groups are 13 and 23. Second group is increasing from the left-top to the right-bottom. The appropriate groups are 43, 53, and 63. The other group is increasing from the top to the bottom. The appropriate group is 33. The results of component planes for advanced course students are complicated than the other courses. Advanced course students might be seriously considering their educational skills because they had finished many ICT classes.

Similar skills in the SOMs are thought to be highly relevant skills in the student's consciousness. It is difficult to teach many skills in class. Some similar skills might be able to be replaced by a few skills. There is a possibility that an effective lesson can be realized without imposing load to teachers and students. Even

now we have set educational goals and performance indicators for each lesson, but they were not analytical methods. Using the SOM results, we try to set more effective educational goals and performance indicators for each lesson.

## 5. CONCLUSION

We have propose developing a method to set key educational skills which students need to achieve for each class using a student self-assessment questionnaire in analytical approach. It is difficult to set key academic skills for class since there are little systematic methods to set them. The questionnaire survey with 25 educational skills has been conducted to ICT classes in our university using a CAWI technique. The questionnaire results have been analyzed using SOMs. A SOM is used to visualize the similarity relations between educational skills based on student's consciousness. We have showed that 25 skills were classified into several skill groups of introduction, fundamentals, and advanced courses, respectively. Present and Future works focus on the improving class contents, the setting effective educational goals, and performance indicators for each lesson using SOM results.

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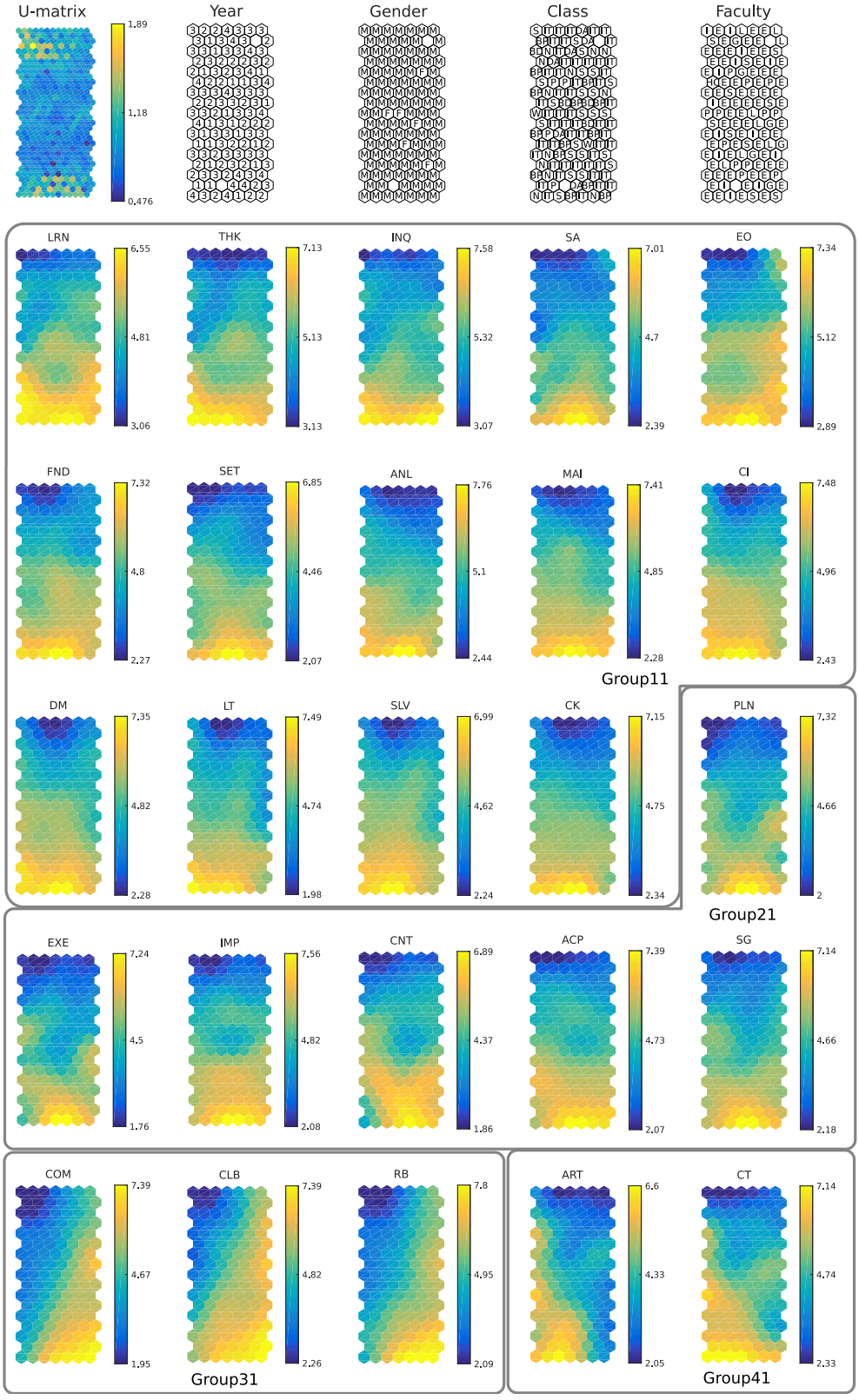


Figure 1. U-matrix, the labels, and the component planes for introduction course

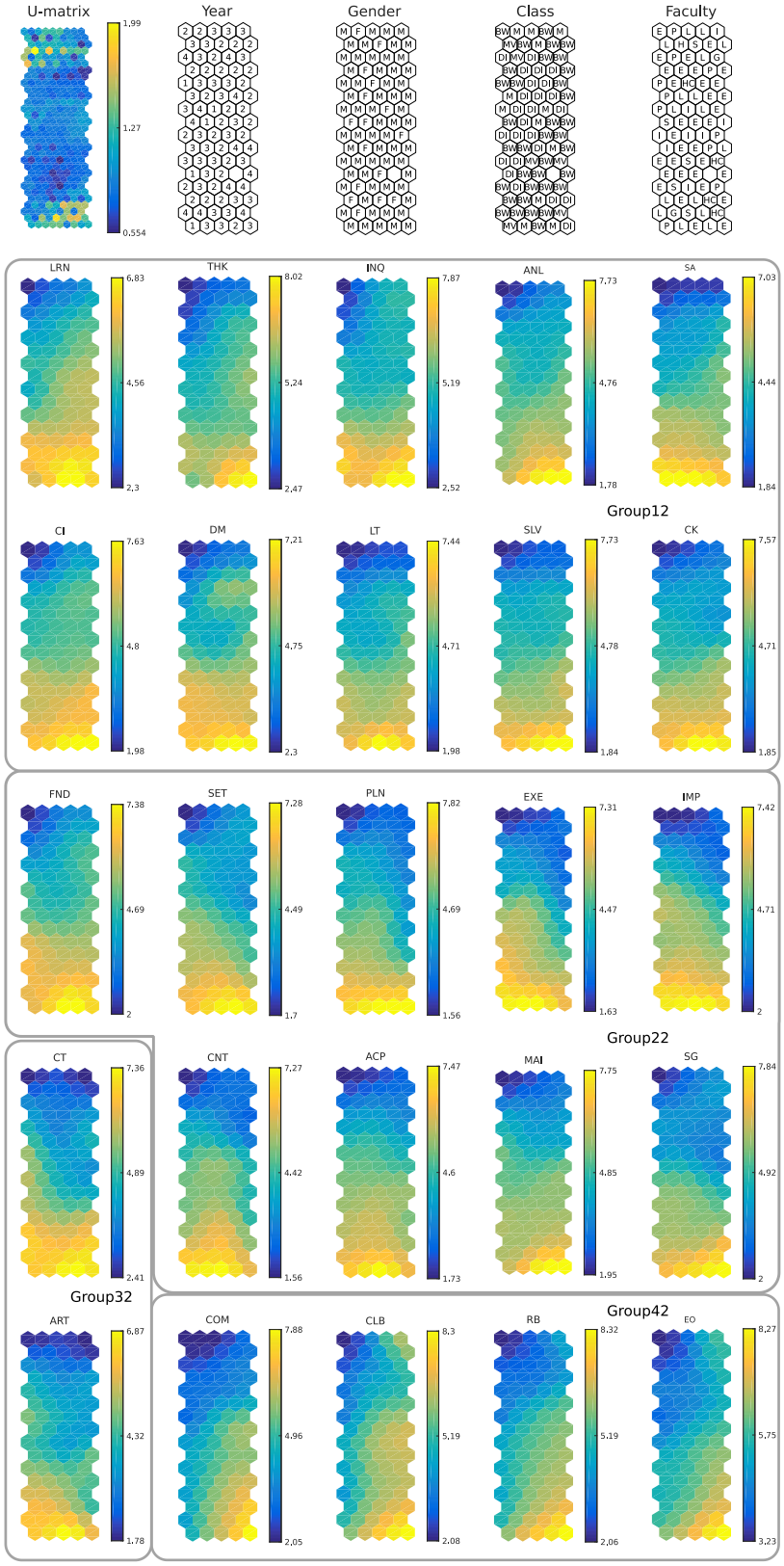


Figure 2. U-matrix, the labels, and the component planes for fundamentals course

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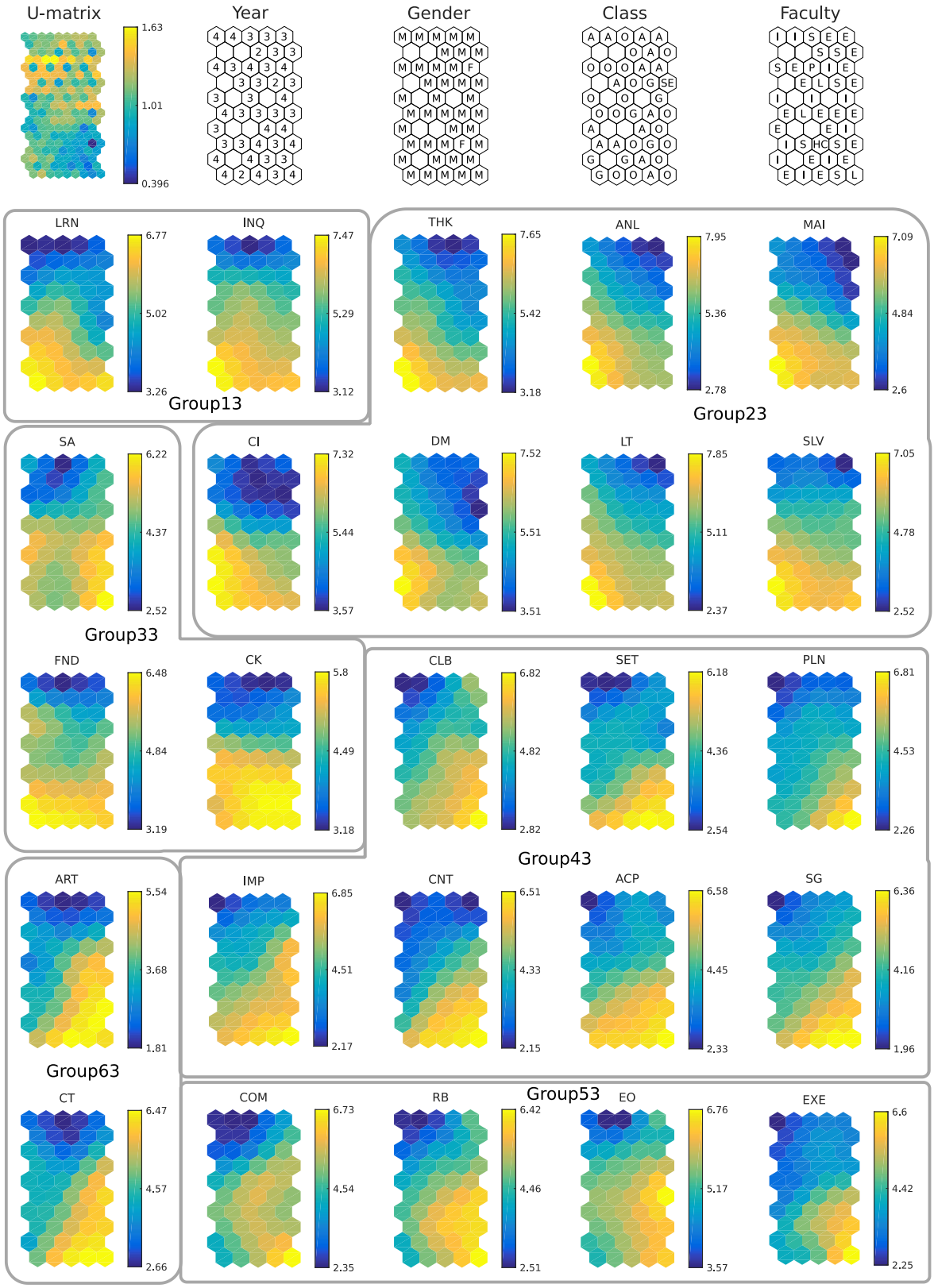


Figure 3. U-matrix, the labels, and the component planes for advanced course