The need of mathematical literacy competency for informatics graduates: Preliminary study at STMIK STIKOM Indonesia

I K B Sandika*, E D Krisna and I N T Anindia

Department of Informatics Engineering, STMIK STIKOM Indonesia, Denpasar, Indonesia

*ikbsandika@stiki-indonesia.ac.id

Abstract. This study aimed to determine the category of needs of competency of mathematical literacy for graduates of informatics bachelor’s degree and analyzing the suitability of the material taught on the group of mathematics subject at STMIK STIKOM Indonesia with the requirement of graduate mathematical literacy competence. The research design that has been used was mixed methods research with concurrent strategy (concurrent mixed methods). This method is chosen to streamline research time, as well as to produce comprehensive data (qualitative and quantitative data) at almost on the same time. The data obtained were analyzed descriptive-quantitatively. The mathematical aspects of the mathematical literacy competencies were evaluated consist of eight dimensions, namely (1) the ability to think and use logical reason in mathematics, (2) argue mathematics, (3) mathematical communication, (4) mathematical modelling, (5) propose and solve mathematical problems, (6) ) representations, (7) symbols, and (8) tools and technologies. The results shown that the competence of the taught mathematical literacy is "sufficient required" by graduates. In addition, there is an indication of the lack of conformity between the learning outcome which was formulated in the curriculum and the real competencies which were required by graduates.

1. Introduction

High education is one of the formal education levels which is held to provide life skills for learners as a preparation for him to participate in their society (education for life) and get an education for earning living from the skills he has learned/possessed [1,2]. From these two objectives, it was developed into four [2], that called as four universal roles of education [3], namely empowering everyone to contribute to work and society, training and developing individual learners' talents, enabling learners to take civil responsibility, and preserving traditions and values in future generations.

To achieve these goal, educational institutions develop curriculum as a guide in the implementation of their education process. To complete undergraduate education, including in informatics engineering programs, students are required to take lectures and can collect a minimum of 144 credits. STMIK STIKOM Indonesia offers 120 credits of compulsory subjects, 15 credits of compulsory concentration subjects, and 9 credits of elective subjects [4].

Among the groups of compulsory subjects, there are several subjects related to mastering mathematical abilities, such as calculus (I and II), numerical methods, linear algebra, statistics, operations research, and discrete mathematics. The questions that arise are related to the meaning or usefulness of mastering these subjects so that it must be taught to students of information technology
programs. Are the material and case studies provided really beneficial for all students, whether mastering these subject would supports or becomes the basis for understanding concepts related to the field of informatics engineering, can understanding the subject provide benefits in solving real problems in the world of work or social life [5]. However, none of the answer of those questions were given. The emphasis which was given is that the subjects that are prepared to be offered in the curriculum are to deliver students to achieve the competencies which is set by the institution (supply driven).

In fact, the experts at the SIGCSE ACM forum stated that mathematics (including calculus) in computer science is actually not one of the compulsory subjects that must be taught to all students of computer science programs, except for those who take certain concentrations, such as the field of computer graphics, or image computing and processing [5]. Even so, computer science undergraduate students need to master analytical reasoning skills to be able to develop high-quality software and understand how the software works according to the expected specifications [6].

Along with the increasing curiosity of the answers to the various questions that arise, it is necessary to study mathematical competencies (mathematical literacy) that are really needed in real life (demand), especially by graduates of informatics engineering. This is in line with the principle of developing education for work which is expected to be arranged based on the real needs of the world of work (demand-driven). This research were conducted to evaluate these reason.

1.1. Need analysis
Analysis was needed by carrying out through a process, starting from preparation, data collection, data analysis and reports, which ultimately the information obtained is used by policy holders [7]. At the preparation stage, it is very important to consider who the research respondent is, the method was used to collect the information needed from the respondents, the resources needed for data collection and analysis, and the scheduling of the implementation in order to achieve the objectives of this analysis. The second stage in analyzing the needs is data collection. The process involves developing a general and detailed plan for obtaining information, specification of procedures and information sources, actual data collection process, and storage of collected information.

At the data analysis stage, sorting, counting and explanation of information are carried out; interpretation of findings obtained; and concluding the results of the needs. The results or findings in this needs analysis process are made in the form of reports. The purpose of making the report is to provide a description of the process and results of needs analysis that are accurate, traceable, easy to understand, and useful to the relevant readers. Therefore, the analyst must have mastery of good communication skills and be able to write, deliver, and present information clearly. The last stage of the needs analysis process is the use of information from the analysis result. The resulting information can be part of a program evaluation that will be used in the pre-program analysis phase (basic planning) or post-program analysis (assessing program impacts), assessing program achievements, determining whether initial needs are still needed, and identifying new needs in the area.

The term of competency refers to a behavior that shows how a person achieves certain skills and performance standards [8]. Tucker and Cofsky state that a competency has five main components, namely knowledge, skills, self-concept, nature, and motives [8,9]. Furthermore, the components of knowledge and skills tend to be easier to see and show the characteristics of a person on the surface [8]. Meanwhile, the components of self-concept, nature and motives are more hidden, deeper and closer to the center of personality.

Literacy can be viewed as an integrated ability to be able to play a role in a particular practical community [10]. Mathematical literacy is an individual's capacity to identify and understand the role of mathematics in life, make sense consideration and use and engage with mathematics in a way that meets the individual's needs as citizens in a constructive, caring and reflective manner [10,11]. There are some differences between mathematical literacy and quantitative literacy [12]. Someone is declared mathematically literate if they master a number of mathematical concepts and can use them in the context of mathematics, but not necessarily able to apply them widely to the context of everyday life.
While someone who is literate quantitatively is someone who may only know a small part of mathematical concepts, but they are able to apply it widely in the context of everyday life.

Mathematical literacy competency is the ability of a person to demonstrate understanding, consideration, and/or application of mathematics to meet their individual needs at work or as part of society/citizens. This ability is characterized by mastering eight main competencies in the aspects of mathematics, namely (1) mathematical thinking and reasoning, (2) mathematical argumentation, (3) mathematical communication, (4) mathematical modeling, (5) proposing and solving mathematical problems, (6) representation, (7) symbols, and (8) tools and technology [10,13]. The indicators for each competency, as shown in Table 1.

| Dimension | Indicator |
|-----------|-----------|
| 1. The ability to think and reason mathematically | a. the ability to ask questions that are characterized by mathematics  
   b. knowing the types of answers that offered mathematically to the question  
   c. to distinguish various kinds of statements (theorems, hypotheses, conditional certainty, etc.)  
   d. understand and use the expansion and limits of mathematical concepts in solving a problem |
| 2. The ability to argue about mathematics | a. find out what is meant by proof / mathematical truth  
   b. able to explain differences in mathematical evidence with other forms of mathematical reasoning  
   c. follow and assess a wide range of arguments  
   d. have a heuristic feeling (the desire to investigate for yourself)  
   e. create and submit mathematical arguments |
| 3. The ability of mathematical communication | a. the ability to express ideas in various forms, either verbally, in writing, or in other visual forms  
   b. understand the results of the work presented by others |
| 4. The ability to do mathematical modeling | a. able to arrange the real conditions to be modeled  
   b. translating reality into mathematical forms  
   c. interpret mathematical models according to their context or reality  
   d. work with mathematical models  
   e. model test / validation  
   f. imagine-analyze-offer suggestions / criticism of a model or solution / mathematical solution  
   g. reflect on the modeling process |
| 5. The ability to submit and solve mathematical problems | a. the ability to submit, formulate, define, and solve problems in various ways |
| 6. Understanding representation | a. ability to decipher the contents of the code  
   b. write in the code  
   c. translate, differentiate, and interpret different forms of representation from mathematical objects and situations  
   d. understand the relationship between different representations  
   e. ability to choose and move between different forms of representation according to the situation and needs |
| 7. Understanding of symbols | a. ability to use symbolic, formal and technical language and operations |
| 8. Use of assistive devices and technology | a. the ability to use calculating aids, including the technology (programs / applications) needed |

2. Research methods

To get a good results of the needs analysis in this study, a mixed method was chosen with concurrent mixed methods. This method was chosen, in addition to streamlining research time, also to be able to produce comprehensive data. The researcher collects two types of data (qualitative and quantitative) in an almost same time span, then combines them into one information in the interpretation of the overall results. Researchers bring together quantitative and qualitative data to obtain a comprehensive analysis of research problems [14].

In this study, the object of the research focus was mathematical literacy competencies, especially those needed by graduates in informatics. Operational mathematical literacy competency in this study
is defined as the ability of graduates of informatics programs to demonstrate understanding, consideration, and/or application of mathematics in the work carried out or further education they take. The capabilities referred to are including some and/or all of the main competencies which are aspects of mathematics, namely (1) the ability to think and reason mathematics, (2) argue mathematics, (3) mathematical communication, (4) mathematical modeling, (5) submit and solve mathematical problems, (6) representation, (7) symbols, and (8) tools and technology.

The population in this study were all students who have graduated at least 1 year at STMIK STIKOM Indonesia for Informatics Engineering Study Program. The number of graduates from graduation period I (May 2012) to period VII (February 2016) totaled 748 people. For preliminary studies, questionnaires were distributed to 20 respondents as samples.

The main data collection techniques used were interviews and questionnaires. In this study, the object of the research focus was mathematical literacy competencies, especially those needed by graduates in informatics engineering programs. Operational mathematical literacy competency in this study is defined as the ability of graduates of informatics engineering programs to demonstrate understanding, consideration, and/or application of mathematics in the work carried out or further education they take.

Data obtained, qualitative and quantitative data, were analyzed quantitatively descriptively. The stages are passed, starting from the sorting process, calculating the central tendency of the data and explanation of information, interpreting the findings obtained, and summarizing. For quantitative data obtained from the results of questionnaires, was analyzed using tendency of centrality (average). The need level of mathematical literacy competencies is determined from the mean value that is converted to a value on a scale of 100. Requirement qualification is determined using a modified benchmark reference assessment criteria, as shown in Table 2.

| Average Acquisition Score | Value Score Interval | Qualification Level          |
|---------------------------|----------------------|------------------------------|
| > 3.36                    | 90 – 100             | Desperately needed/required  |
| 3 – 3.56                  | 75 – <90             | Needed/required              |
| 2.2 – <3                  | 55 – <75             | Sufficiently needed/required |
| 1.6 – <2.2                | 40 – <55             | Less needed/required         |
| 0 – <1.6                  | 0 – <40              | Not/very less needed/required|

3. Results and discussions

3.1. Results
When viewing from the average score of each dimension of mathematical literacy competency tested, the highest value obtained quantitatively was the use of tools and technology dimensions, and the lowest value was to dimensions of proposing and solving mathematical problems. However, qualitatively related to the level of need for each dimension of mathematical literacy competency, the dimension of proposing and solving mathematical problems and the ability to think and reason math were categorized as less needed, while the other six dimensions fall into the category of sufficient need. The summary of the mean scores for each dimension and qualification of the level of needs as shown in Table 3.
Table 3. The Requirement Level of Mathematical Literacy Competencies for Informatics Graduates.

| Dimension No. | Indicator No. | Indicator Mean Score | Dimension Mean Score | Dimension Value Score | Qualification Level |
|---------------|---------------|----------------------|----------------------|-----------------------|---------------------|
| 1             | a             | 2.550                | 2.194                | 54.844                | Less required       |
|               | b             | 1.950                |                      |                       |                     |
|               | c             | 2.600                |                      |                       |                     |
|               | d             | 1.675                |                      |                       |                     |
|               | a             | 2.600                |                      |                       |                     |
|               | b             | 2.400                |                      |                       |                     |
|               | c             | 2.400                |                      |                       |                     |
|               | d             | 2.250                |                      |                       |                     |
|               | e             | 2.350                |                      |                       |                     |
| 2             | a             | 2.400                | 2.400                | 60.000                | Sufficiently required |
|               | b             | 2.583                |                      |                       |                     |
|               | c             | 2.650                |                      |                       |                     |
|               | d             | 2.500                |                      |                       |                     |
|               | e             | 2.700                |                      |                       |                     |
|               | a             | 2.300                | 2.475                | 61.875                | Sufficiently required |
|               | b             | 2.400                |                      |                       |                     |
|               | c             | 2.475                |                      |                       |                     |
|               | d             | 2.300                |                      |                       |                     |
|               | e             | 2.15                 | 2.15                 | 53.750                | Sufficiently required |
|               | f             | 2.533                | 2.533                | 63.333                | Sufficiently required |
|               | g             | 1.975                | 1.975                | 49.375                | Less required       |
| 5             | a             | 1.975                | 1.975                |                      |                     |
|               | b             | 2.750                |                      |                       |                     |
|               | c             | 2.250                |                      |                       |                     |
| 6             | a             | 2.450                | 2.450                | 61.250                | Sufficiently required |
|               | b             | 2.850                |                      |                       |                     |
|               | c             | 1.950                |                      |                       |                     |
| 7             | a             | 2.150                | 2.150                | 53.750                | Sufficiently required |
| 8             | a             | 2.533                | 2.533                | 63.333                | Sufficiently required |
| Average       |               |                      | 58.340               |                       | Sufficiently required |

This is in line with the results of the interviews, as stated by Mr. IPAP that the most dominant mathematical competencies needed to support work in business only revolves around basic math counting operations (addition, subtraction, multiplication, division, percentage).

3.2. Discussion

Based on the data above, it can be seen that the level of mathematical literacy competency needs in the opinion of the graduates of the informatics engineering study program is sufficiently needed with a mean value scale of 58.340 (see Table 3). The order of mathematical literacy competency dimensions from the highest to the lowest is the dimension of understanding representation, mathematical argument ability, the use of tools and technology, the ability to do mathematical modeling, mathematical communication skills, the ability to propose and solve mathematical problems, understanding symbols, and finally is ability to think and reason mathematically. Thus, it can be stated that the competencies expected by graduates are more dominant with regard to the ability to translate/interpret or understand the relationships between different forms of representation of mathematical objects or specific situations, including describing the contents or code and writing mathematical codes.

To facilitate learners in understanding various forms of representation, educators need to emphasize on verbal representation [15].

If the results are related to the implementation of the curriculum in STMIK STIKOM Indonesia, it is not yet fully in line. One example in mathematics course 1, stated that the targeted learning outcomes are mastery of theoretical concepts of mathematics in general. This achievement includes the dimensions of mathematical thinking and reasoning skills in the concept of mathematical competence literacy. By referring to the research data obtained, these achievements are actually less needed by graduates. If this continues, it can lead to a gap between the material taught during lectures and real needs in the real work field. Therefore, there needs to be an adjustment to the curriculum to better suit the needs of graduates in the real work field.
4. Conclusions
Based on the description of the data and discussion of the results of the research above, it can be concluded that:

- The material or subject matter that needs to be mastered to show someone has mastered mathematical literacy competencies consists of eight dimensions, namely mathematical thinking and reasoning skills, mathematical argumentation, mathematical communication, mathematical modeling, propose and solve mathematical problems, representation, symbols, and tools and technology.
- According to the assessment of graduates of Informatics Engineering students, mathematical literacy competencies fall into the category of "sufficiently needed competence".
- Based on the discussion about the suitability of the material taught in the lectures of the mathematics group courses at STMIK STIKOM Indonesia with the needs of graduate mathematical literacy competencies, there were indications of a lack of compatibility between targeted learning outcomes and the real competencies needed by graduates.

Based on the conclusions of the research results above, several further study suggestions can be proposed, as follows:

- There needs to be further research with more and more proportional respondents and more in-depth interviews to test the validity and reliability of research data.
- Further research is needed regarding the needs of mathematical competencies as supporting competencies in other informatics techniques (concentration courses).
- More thorough evaluation is needed regarding the suitability of the lecture material with the real competencies needed.

Acknowledgment
This research and publication was supported by LPPM STMIK STIKOM Indonesia.

References
[1] C R Finch and J R Crunkilton 1999 *Curriculum development in vocational and technical education: Planning, content, and implementation* (Boston: Allyn and Bacon)
[2] I K B Sandika 2016 *Pengembangan Model Kemitraan Pendidikan Kejuruan dengan Dunia Usaha pada Program Studi Keahlian Teknik Bangunan SMK di Bali* (Universitas Negeri Yogyakarta)
[3] B Trilling and C Fadel 2009 21st century skills-Learning for life in our time (San Fransisco: Jossey-Bass)
[4] Program Pendidikan | STMIK STIKOM Indonesia [Online] Retrieved from: http://stiki-indonesia.ac.id/program-pendidikan/ Accessed on: 12-Oct-2017
[5] I Pramusinto 2012 Mengapa Belajar Kalkulus? Menghadirkan motivasi Mahasiswa dalam mengikuti kuliah,” in *Pembelajaran Teknologi Informasi di Perguruan Tinggi: Proses dan Pengalaman*, F. Wahid and T. Dirgahayu, Eds. (Yogyakarta: Graha Ilmu)
[6] S V Drachova, J O Hallstrom, J E Hollingsworth, J Krone, R Pak and M Sitaraman 2015 Teaching Mathematical Reasoning Principles for Software Correctness and Its Assessment *ACM Trans. Comput. Educ.*
[7] D L Stufflebeam, C H McCormick, R O Brinkerhoff and C O Nelson 1985 *Conducting educational need assessments* (Boston: Kluwer-Nijhoff Publishing)
[8] S. Sanghi 2007 *The handbook of competency mapping: understanding, designing and implementing competency models in organizations* (New Delhi: Vivek Mehra for Sage Publications)
[9] V S Chouhan and S Srivastava 2014 Understanding competencies and competency modeling-A literature study *IOSR J. Bus. Manag.* 16 1 pp 14–22
[10] S Hadi 2017 *Pendidikan matematika realistik: Teori, pengembangan, dan implementasinya* (Jakarta: Rajawali Pers)
[11] OECD 2016 *PISA 2015 assessment and analytical framework: Science, reading, mathematic and
financial literacy (Paris: OECD Publishing)

[12] D H Hallet 2003 The role of mathematics courses in the development of quantitative literacy,” in Quantitative literacy: Why numeracy matters for schools and colleges, B. L. Madison and L. A. Steen, Eds. Princeton, NJ: National Council on Education and the Disciplines pp 91–98

[13] J de Lange 2003 Mathematics for literacy,” in Quantitative literacy: Why numeracy matters for schools and colleges, B. L. Madison and L. A. Steen, Eds. Princeton, NJ: National Council on Education and the Disciplines pp 75–89

[14] J W Creswell 2009 Research Design: Qualitative, Quantitative and Mixed Approaches (3rd Edition) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches pp 1–295

[15] S M Matteson 2006 Mathematical literacy and standardized mathematical assessments Read. Psychol.