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# K-Means clustering model to improve competency of diploma program graduates

**Hanung Nindito Prasetyo**, Telkom University, School of Applied Science, Department of Information System Diploma, Bandung, 40257, Indonesia, https://orcid.org/0000-0001-5717-9337

**Wawa Wikusna**, Telkom University, School of Applied Science, Department of Information System Diploma, Bandung, 40257, Indonesia, https://orcid.org/0000-0001-7733-5376

**Ferra Arik Tridalestari***, PGRI University of Yogyakarta, Faculty of Business, Department of Digital Business, Yogyakarta, 55182, Indonesia, https://orcid.org/0000-0002-9848-6728

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**Abstract**

Completion of studies by students is the result of the process carried out in the learning process in university. The problem that arises related to this condition is that many diploma students are often late in completing their studies or even dropping out of school. Departments at the university do not have a significant measuring tool in predicting student graduation rates based on the competencies mastered. This paper proposes a program model to predict the basic abilities of Information System Diploma Program students to be mapped in the level of ability in an effort to reduce the delay in the learning process. The method used in the program model was a quantitative method with a K-Means Clustering model approach. The results showed that there was a significant increase in the timely graduation rate for Information System Diploma Program.

Keywords: Graduates Competency, Diploma Program Student, Information System, K-Means Clustering, Higher Education;

*CORRESPONDENCE ADDRESS: Ferra Arik Tridalestari, PGRI University of Yogyakarta, Faculty of Business, Indonesia.
Email address: ferraarik@upy.ac.id / Tel.: +6281220599884

## 1. Introduction

Universities as entities in improving student competencies have an interest in developing learning programs. A structured learning program has the aim of delivering students to achieve competence and find the desired career (Collins et al., 2021). Education is a joint effort of universities and related stakeholders in creating a learning atmosphere and learning process so that students are actively able to develop their potential to have good self-control, personality, and character and skills needed by themselves and the community (Hidayah, 2021). Universities have an important role and position among the components of education. The purpose of higher education is to provide services that contain elements of limited norms but do not conflict with the nature of student development and can be well accepted by the community as the value of a good life (Moscardini et al., 2020; Nagarajan & Edwards, 2015). This is no exception to the Information System Diploma Study Program at Telkom University. Study programs that have many students with limited teaching resources must run an efficient and effective learning process. However, the study program is faced with fundamental problems that become obstacles in carrying out the learning process.

The educational process has a time limit determined by the university, according to the level of education. To take a level of education, students must follow the regulations that have been applied by the university. If exceeding the time limit, the student is declared to have failed in carrying out the educational process. Study time limit is the maximum time for a student to complete study in a higher education institution. The length of study taken is regulated or determined by universities in Indonesia (Pendidikan & Indonesia, 2020). The Information System Diploma Study Program has the following rules:

- The length of study at the diploma level in the Information System Study Program is between three to five years.
- Students who have exceeded the maximum study time are declared “drop out” (DO), with a decision letter that is issued by the head of the university at the suggestion of the dean of the faculty.

This is a consequence of educational regulations because of the large number of students. This is in line with research results that with limited education many students are often late in completing their studies and even drop out of school (Zuilkowski et al., 2019). An important problem faced by the Information System Diploma Study Program at Telkom University is the low timely graduation rate. Until 2016, the average diploma student who graduated on time was only 60%. This shows that the remaining 40% graduated late even dropped out. Delays in completing studies caused the burden of the learning process and the burden of lecturers to increase. In addition, the Study Program was also faced with the problem of difficulty in determining the final task that must be completed by students so that students found their own and completed the final project independently. To solve this problem, the department explored the problem that occurred. The Information System Diploma Study Program made observations to students regarding the problem of completing their final studies. The results of observations made by researchers on Class 2016 students showed that 59% had difficulty finding a final project topic for study completion, 32% did not know where to start in completing the final project, and 9% had other factors.

### *1.1 Conceptual Framework*

Based on the problems above, we propose a new approach to the Information System Diploma Study Program, which is to group students' basic vocational skills by using data on certain subjects selected according to the 2010 Computing Curriculum (Isbell et al., 2009) and the SFIA Framework (J. Brown, 2020). Predictions made based on student course data at the beginning of the semester are then

mapped through the HWF (Hanung-Wawa-Ferra) Cycle on the dynamic program proposed by the Study Program. By doing the HWF cycle, the Information System Diploma Study Program has a program that can be a solution and help students complete their studies on time.

### *1.2 Related Works*

There is quite a lot of researches related to grouping the abilities of students or people, such as research conducted by Antlová (2008). This research focuses on Information System competencies required by medium and small industries. The approach used was data mining methods, namely decision tree classifier, clustering, and association rules, to find competencies that are very influential on the long-term growth of a company. Another research is research conducted by Ariana et al. (2020). The purpose of this research is to measure the willingness of Information and Communications Technology (ICT) human resources to introduce e-government. This was done by introducing a resource-based view (RBV) to measure and classify ICT HR competence based on three indicators: technical competence, management competence and alignment. In addition, these indicators were measured using gap analysis and clustering techniques (Ariana et al., 2020).

Another interesting study is that of Lo, K.H et al. The research is about how the Hospital managers recognize the need to make their clinical staff more competitive, and patient-centered care models require innovation and continuous quality improvement to improve service quality and hospital competitiveness. The study uses two levels of grouping (Independent Organizational Map and K-Means) to identify different types of departments such as physicians, medical staff, and administrators, and to describe the core competencies of each group. This result shows how important it is to communicate core competencies to different hospital departments and units. (Kuei-Hsing Lo, Wen-Tsann Lin, Jou Yung-Tsan, 2018).

Other related research is research conducted by Ufuk Bolukbas (2017). The purpose of this study is to assess the technology management performance of SMEs so that comparisons can be made between firms in different clusters. K-Means cluster analysis was applied to the survey data to analyze and evaluate the performance of a manufacturing company in Istanbul, Turkey. As a result, a company's technological prowess is determined by 3, 4, and 5 clusters. Other related research is research conducted by Akarawang et al.(2015). This study aims to assess the needs and training to improve ICT competence. There were 377 teachers and 12 principals, supervisors and professional teachers from 35 schools were interviewed to identify issues and training needs. The results indicated that the teacher needed training that focused on acquiring practical skills and deepening her understanding of ICT.

Based on the related literature, there are several researchers who have the same thoughts in research, but research that specializes in grouping skills or competencies of Information System students as predictions to be mapped in a dynamic and sustainable study completion program has not been found. The HWF cycle as the basis of programming is something new as a contribution in this paper.

### *1.3 Purposes of the Study*

The purpose of this study is to produce a consistent model in measuring the competence of Diploma Program graduates on an ongoing basis in accordance with the characteristics of students in completing studies in the field of Information System.

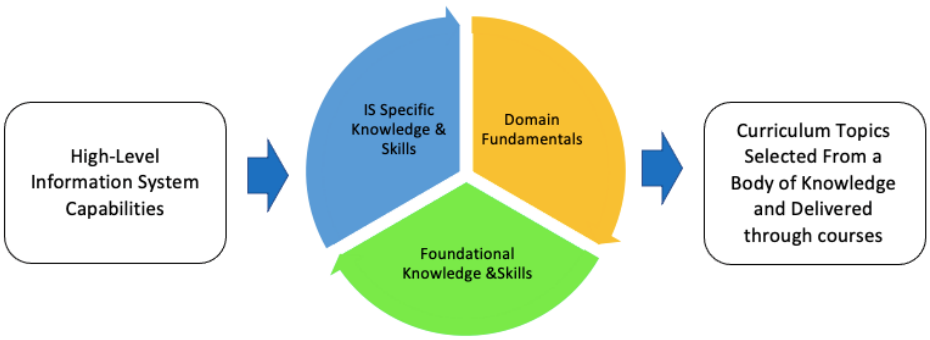
## 2. Materials And Methods

### *2.1 Information System Vocational Competency*

Vocational courses in the Information System Diploma Study Program at School of Applied Science of Telkom University are guided by the 2010 Computing Curriculum and the British SFIA framework (J. Brown, 2020; Isbell et al., 2009). This ability is based on knowledge and skills that have been categorized as specific knowledge and skills for Information System graduates. Figure 1 shows how skills are translated into curriculum documents.

**Figure 1**

*High-Level Information System Capabilities*




The use of the IS 2010 ACM Curriculum as the basis in this paper is because the data used is still based on the curriculum and further research is certainly needed for further development in the use of the IS 2020 curriculum (Isbell et al., 2009). Meanwhile, the SFIA Framework divides competencies into six categories as shown in Figure 2.

**Figure 2**

*SFIA Framework (J. Brown, 2020)*


Figure 2 shows that SFIA divides the competency areas into six main categories, namely: strategy and architecture, business change, solution development and implementation, service management, procurement and management support, and client interface.

### *2.2 Courses Selection*

The selection of courses as a tool for predicting basic vocational skills and the selection of basic courses delivered in the first semester of student learning are adjusted to the curriculum that is run

based on the IS 2010 Computing Curriculum and the SFIA Framework. In addition, the concept of information system strategy is also considered, which includes Organization, Business, and Technology (Rahro & Soleymani, 2017). The overall mapping can be seen in Table 1.

**Table 1**

*Mapping Framework used by the Department*

| No | IS 2010 Computing Curriculum | SFIA Framework | Basic Information System Competency Course |
|---|---|---|---|
| 1 | Improving organizational processes<br>Seizing opportunities due to technological innovation<br>Identifying and evaluating alternative solutions and sources | Strategy and Architecture,<br>Service Management,<br>Procurement and management support | Introduction to Management |
| 2 | Designing and managing enterprise architecture<br>Understanding and addressing information needs | Business Change | Business Process |
| 3 | Protecting data and infrastructure, as well as<br>Understanding, managing, and controlling risks. | Solution Development and implementation,<br>Client interface | Information System Design and Analysis |

### *2.3 K-Means Clustering*

K-means clustering is a simple and elegant approach to partitioning a dataset into K distinct, non-overlapping clusters. To perform k-means clustering, we first need to determine the number of k-clusters we want. Then the k-means algorithm assigns exactly one cluster to each observation. (Bansal et al., 2017). The K-means algorithm is a non-hierarchical method that initially takes part of the population to be the initial cluster center. At this stage, the cluster center is randomly selected from a set of population data. Next, K-means tests each component in the data population and assigns that component to one of the predefined cluster centers depending on the minimum distance between the components and each cluster. The position of the cluster center will be recalculated until all data components are classified into each cluster center and finally a new cluster center position will be formed (Ahmad & Dey, 2007).

K-Means Clustering Algorithm provides easy implementation, very flexible, and easy to use adaptation. In addition to the time needed to do learning faster, it also uses simple principles that can be explained in non-statistical terms. This is the reason for using K-means clustering compared to other methods (Maylawati et al., 2020; Shabut et al., 2018). Determination of clusters in K-Means clustering using the Davies Bouldin Index (BDI) indicator. Davies Bouldin index (DBI) is a metric to evaluate or consider the results of clustering algorithms. By using DBI a cluster will be considered to have an optimal clustering scheme which has a minimum DBI (Karo et al., 2018).

## 3. Methodology

### 3.1 Research Model

This study used a quantitative approach. The flow of research carried out is as shown in the Figure 3

**Figure 3**

*Research Flow*


Figure 3 shows the flow of the research carried out. The steps taken were:

- Problem Identification
  Problem identification is done to find and understand the main problems encountered. Identification is carried out thoroughly both for human problems (in this case, students and lecturers), identification in engineering problems, or related work structures and phenomena that occur (R Kumar, 2018).
- Study Literature
  This stage is carried out for data collection techniques by conducting a review study of books, literatures, notes, and reports that have to do with the problem being solved (P. A. Brown, 2008).
- Observation
  This stage needs to be done to strengthen the previous literature study stage. Observation also means observing and recording the subject or event in a systematic way. This is done to minimize errors in decision-making or modeling (Baker, 2006).
- Program Modeling
  Modelling is the process of generating models. The model is a representation of the construction and work of some interesting systems. The model is made similar to but simpler than the system it represents. One of the goals of the model is to enable the analyst to predict the effects of changes on the system (Maria, 1997). The model is generated through observation and Forum Group Discuss with the Delphi method approach (Alarabiat & Ramos, 2019). This technique is very flexible to be applied in various situations and complex problems, in which there is often no suitable analytical method to be applied (Fink-Hafner et al., 2019).
- Implementation
  At this stage, the implementation of the model is carried out to see the performance of the model as well as to evaluate the model.
- Result
  The research results are obtained to evaluate the research that has been done and to find the potential for future development.

### *3.2 Participants*

The research data used the data population of students of Information System Diploma Program at Telkom University in 2016.

### *3.3 Data Collecting Tool*

The data was obtained from the academic system of Igracias at Telkom University. Igracias is academics Information system of Telkom University. The data used was data on the value of the subjects

that are the focus of the research, namely the Introduction to Management, Business Process, and IS Design & Analysis.

### *3.4 Data Collecting Process*

The data collection process was carried out by filtering the data, selecting the year, and generating it on the Igracias Academic system at Telkom University.

### *3.5 Data Analysis*

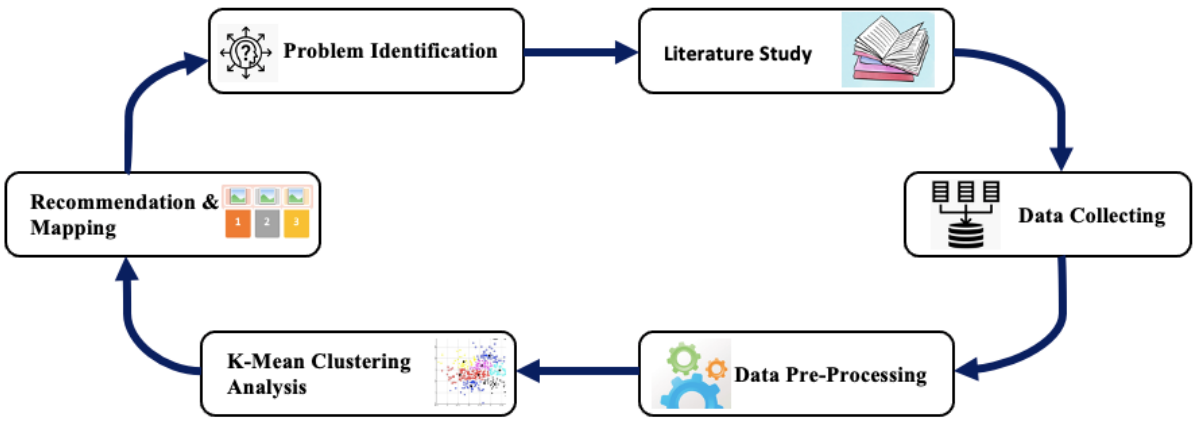
Analysis of the data in this study used the K-Means Clustering approach with the Davies Bouldin Index (BDI) indicator.

## 4. Result & Discussion

### *4.1 Program Modelling*

The HWF Cycle model is generated based on the results of observations, literature study, and Forum Group Discuss (FGD) in the Information System Diploma Study Program, as shown in Figure 4.

**Figure 4**
*HWF Cycle Model*




The detailed flow of the HWF Cycle is as follows:

- Identifying the problem

  This stage is to identify the problems faced by the Information System Diploma Study Program related to students' confusion and delays in completing studies.

- Literature review

  At the literature review stage, a literature study is conducted related to research topics through information analysis of the basic competencies of Information System, analysis of the IS 2010 ACM Curriculum, scientific articles on the Scopus journal database, and so on.

- Data collection

  The data collection stage is carried out after determining the elective courses that are the reference in the basic competencies of Information System. At this stage, data is filtered from the Igracias Academic information system database, Information System Diploma Study Program, School of Applied Sciences, Telkom University.

- Pre-processing

  In this stage, pre-processing is carried out to make labels on research data.

- K-Means Clustering Analysis

  At this stage, data processing and analysis are carried out using the K-Means Clustering approach.

- Recommendations

  At this stage, mapping the selected clusters in the program proposed by Information System Diploma Study Program is dynamic. This is because each education force and student will have different conditions so that the problems faced will be different. Therefore, the results of the recommendations will always be evaluated every year and will change according to the problems encountered.

### *4.2 Data Processing Results*

The initial data used previously is as shown in Table

**Table 2**

*Secondary Data Obtained from the Igracias Academic System*

| NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|
| 6701150001 | 64 | 68.25 | 60.25 |
| 6701150006 | 64 | 60 | 50.5 |
| 6701150025 | 70 | 41.25 | 65.7675 |
| 6701150032 | 73.75 | 61.6675 | 57.125 |
| 6701150034 | 79.75 | 71.75 | 80.25 |
| … | … | … | … |
| 6701164160 | 65 | 81.25 | 53.535 |
| 6701164162 | 79.4275 | 70 | 61.4375 |
| 6701164163 | 69.665 | 79.25 | 80.5 |

**Table 3**

*Descriptive Statistics of initial data*

| Course | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Introduction to Management | 251 | 35.43 | 90.00 | 72.8632 | 10.38931 |
| Business Process | 251 | 41.25 | 88.13 | 72.0032 | 6.92222 |
| IS Design & Analysis | 251 | 26.89 | 102.94 | 68.0514 | 11.88744 |
| Valid N | 251 | | | | |

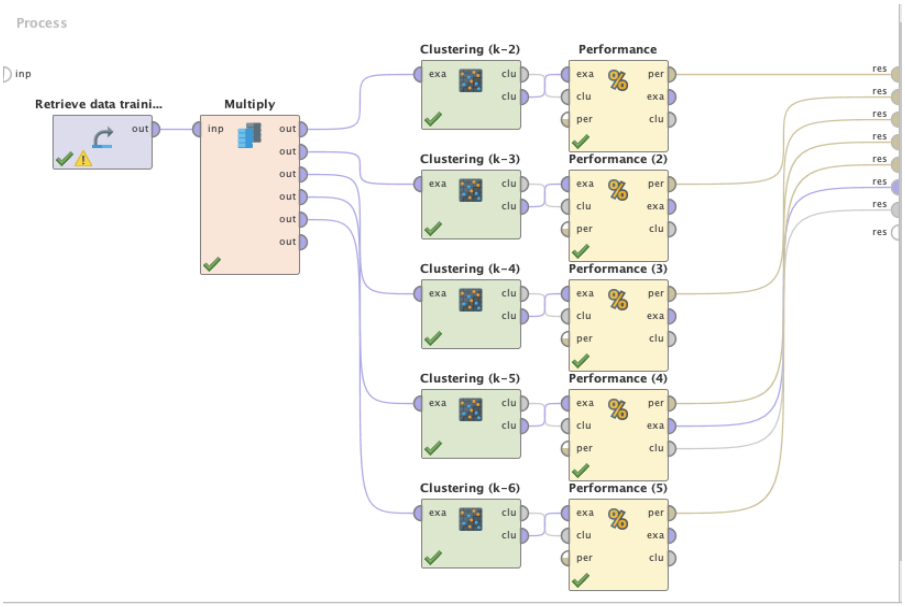
Data in Table 2 shows student competencies in the three core courses of the information System Diploma Study Program, namely Introduction to Management, Business Processes, and IS Design & Analysis. The three courses represent the level of student competence at each level of education. Student competencies at level 1 are represented by Introduction to Management, Business Processes, and IS Design & Analysis courses. Table 3 shows statistical data descriptively. The data shows that the course

that has the best average is Introduction to Management, followed by Business Process, and IS Design & Analysis.

By using Rapidminer, Figure 5 shows performance of the K-Means Clustering Model.

**Figure 5**

*Performance of K-Means Clustering Model*




In Figure 5, cluster selection is carried out by performing five iterations. The first iteration (Clustering (k-2)) is selecting two clusters and then obtaining the Davies Bouldin value. The second iteration (Clustering (k-3)) is selecting three clusters until the fifth iteration (Clustering (k-6)) with the number of selected clusters is 6. Determination of the number of clusters is based on Davies Bouldin values, which is based on data processing using Rapidminer. Davies Bouldin values obtained is as shown in Table 4.

**Table 4**

*Davies Bouldin Values in K-Means Clustering Iteration*

| No | Number of K | Davies Bouldin's Value |
|---|---|---|
| 1 | 2 | 1.148 |
| 2 | 3 | 1.074 |
| 3 | 4 | 1.120 |
| 4 | 5 | 1.054 |
| 5 | 6 | 1.061 |

Based on the Davies Bouldin values, the number of selected clusters is 5. The centroid value of the 5 selected clusters can be seen in Table 5.

**Table 5**

*Centroid Value of Clusters*

| Attribute | Cluster_0 | Cluster_1 | Cluster_2 | Cluster_3 | Cluster_4 |
|---|---|---|---|---|---|
| IS Design & Analysis Score | 76.735 | 65.572 | 63.705 | 79.092 | 47.518 |
| Introduction to Management Score | 82.011 | 49.899 | 75.772 | 67.567 | 65.905 |

| | | | | | |
|---|---|---|---|---|---|
| Business Process Score | 76.825 | 75.785 | 68.862 | 73.032 | 66.641 |

The results of the cluster grouping are as shown in Table 6.

**Table 6**

*Distribution of Data on the 5 Selected Clusters*

| Cluster | Items |
|---|---|
| 0 | 69 |
| 1 | 18 |
| 2 | 86 |
| 3 | 45 |
| 4 | 33 |
| Totally | 251 |

The cluster grouping is as shown in Table 7-11

**Table 7**

*Cluster_0*

| No | NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|---|
| 13 | 6701150034 | 79.75 | 71.75 | 80.25 |
| 18 | 6701150041 | 82 | 87.5 | 72.25 |
| 29 | 6701150108 | 87.5 | 71.55 | 71.25 |
| 30 | 6701150109 | 83.75 | 77.35 | 91.75 |
| … | … | … | … | … |
| 238 | 6701164123 | 83.0325 | 76 | 69.25 |
| 248 | 6701164155 | 90 | 77.25 | 67.3225 |

**Table 8**

*Cluster_1*

| No | NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|---|
| 136 | 6701160011 | 51.3225 | 80 | 73.75 |
| 141 | 6701160023 | 54.68 | 76 | 70.75 |
| 179 | 6701160114 | 41.635 | 71.25 | 65 |
| 180 | 6701160115 | 61.5 | 73.75 | 61.1425 |
| … | … | … | … | … |
| 234 | 6701164079 | 45.615 | 77.5 | 67 |
| 245 | 6701164141 | 51.645 | 73.75 | 64.875 |

**Table 9**

*Cluster_2*

| No | NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|---|
| 1 | 6701150001 | 64 | 68.25 | 60.25 |

| | | | | |
|---|---|---|---|---|
| 4 | 6701150011 | 72 | 73.75 | 55.25 |
| 5 | 6701150015 | 80 | 58.125 | 60.92 |
| 10 | 6701150025 | 70 | 41.25 | 65.7675 |
| … | … | … | … | … |
| 246 | 6701164147 | 65.885 | 70 | 63.75 |
| 250 | 6701164162 | 79.4275 | 70 | 61.4375 |

**Table 10**
Cluster_3

| No | NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|---|
| 7 | 6701150019 | 67.5 | 64.6 | 77 |
| 27 | 6701150106 | 68 | 73.75 | 71.75 |
| 60 | 6701151062 | 68.75 | 64.1675 | 77.75 |
| 93 | 6701154094 | 73.75 | 69.25 | 79.5 |
| … | … | … | … | … |
| 247 | 6701164149 | 68.2675 | 65 | 75.625 |
| 251 | 6701164163 | 69.665 | 79.25 | 80.5 |

**Table 11**
*Cluster_4*

| No | NIM | Introduction to Management Score | Business Process Score | IS Design & Analysis Score |
|---|---|---|---|---|
| 2 | 6701150006 | 64 | 60 | 50.5 |
| 3 | 6701150010 | 65 | 50.9375 | 52.1425 |
| 15 | 6701150038 | 83.75 | 78.35 | 41 |
| … | … | … | … | … |
| 244 | 6701164140 | 53.25 | 66.25 | 43.25 |
| 249 | 6701164160 | 65 | 81.25 | 53.535 |

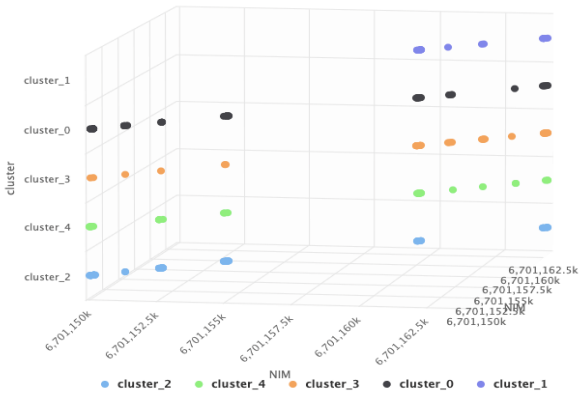
The main purpose of the clustering process is to group objects or cases based on their characteristics. Cluster analysis classifies objects so that each object that has similar properties (closest in similarity) will be grouped into the same cluster (group). In this study, clusters were conducted to see groups of students who have the same characteristics in terms of basic information system abilities.

### *4.3 Clustering Analysis*

The results of data processing using Rapidminer showed that the best cluster was cluster 1, as shown in Figure 6.

**Figure 6**

*Cluster Diagram of Data Processing Results*




Based on the performance of K-Means Clustering as shown in Figure 6 above, it can be seen that the order of clusters from the best is cluster_1, cluster_0, cluster_3, cluster_4, and cluster_2.

### *4.4 Discussions*

Five clusters were obtained in this study. This grouping can be a recommendation for the Information System Diploma Study Program to create a completion program for Information System Diploma Program. The 5 programs compiled are based on the abilities possessed by 5 student clusters, which are based on the basic competencies of Information System Diploma Program.

**Table** **12**

*Mapping of Proposals Based on the Results of Clustering.*

| No | Cluster | Program Level | Description |
|---|---|---|---|
| 1 | Cluster_1 | Superior | Students understand management concepts, are able to reengineer business processes, build information technology-based information system, and complete large industrial application development programs. This level is the highest level because the level faced is relatively difficult. |
| 2 | Cluster_0 | Primary | Students understand management concepts, are able to reengineer business processes, build information technology-based information system, and complete small industry application development programs. At this level, the level of difficulty is high and students work in groups in the information system development team. |
| 3 | Cluster_3 | Secondary | Students understand management concepts, are able to reengineer business processes, build information technology-based information system, and complete government application development programs. This level is included in the middle level category because the applications built are based on processes that generally have a similar model compared to the two previous levels. |
| 4 | Cluster_4 | Tertiary | Students understand management concepts, are able to reengineer business processes, build information technology-based information system, and complete lecturer |

| No | Cluster | Program Level | Description |
|---|---|---|---|
| | | | research application development program. At this level, the level of difficulty is low because the research carried out can be adjusted to student's ability in accordance with the subjectivity of the lecturer as a researcher. |
| 5 | Cluster_2 | Non-Superior | Students understand management concepts, are able to reengineer business processes, build information technology-based information system, and complete the simple application development program. This level is the lowest level that can be completed by students according to their abilities and is free but still adjusts to the minimum standards of the Study Program. |

Through the adjustment of the number of programs that is dynamic, Table 12 shows the adjustment of the program with the results of the cluster of information system basic competencies. The indicator of program difficulty level is based on the results of FGDs from expert judgment lecturers, industry partners, and the government that collaborate with the Information System Diploma Study Program.

### *4.5 Recommendations*

After clustering students based on their competencies, a suitable treatment program is recommended for each student cluster. Table 13 is a recommendation for each cluster of students in order to graduate on time.

**Table 13**

*Mapping of proposals based on the results of clustering*.

| No | Program Level | Competency Improvement Program | Motivation Improvement Program |
|---|---|---|---|
| 1<br>2<br>3 | Superior<br>Primary<br>Secondary | Students are trained to have the ability in time management and project management so that they can optimize their capabilities and resources in a directed and effective manner to achieve the target on time before the deadline for graduating from study. | • Emotional control program<br>• Creative thinking<br>• Commitment to time<br>• Work effectively and efficiently<br>• Communication and collaboration |
| 4<br>5 | Tertiary<br>Non-Superior | Students are trained to be more skilled in the development of software and information system and have the ability in time management and project management so that they can compete with other students to complete larger projects. | • Emotional control program<br>• Creative thinking<br>• Commitment to time<br>• Work effectively and efficiently<br>• Communication and collaboration<br>• Passion for self-development<br>• Not easily discouraged<br>• Positive thinking |

### *4.6 Evaluation*

The program that had been implemented was significantly quite successful. This can be seen from the increase in the timely graduation rate of Information System Diploma Study Program as shown in Figure 7.

**Figure 7**

*Graduation Rate on Time of Students*

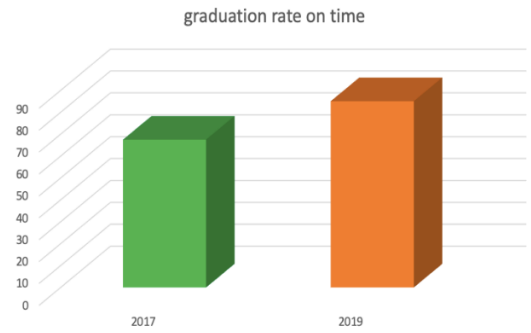



Figure 7 shows that before running this program, the timely graduation rate in the Information System Diploma Study Program only reached 67.48%. Meanwhile, after running this program, the timely graduation rate experienced a very significant increase of 85.04%.

## 5. Conclusion & Future Works

Based on the results of the study, it was concluded that the K-Means clustering mechanism in the HWF Cycle facilitated the Study Program to develop a final project completion program so that students were more focused in completing their final studies. The dynamic nature of the program will be an evaluation material for the Information System Diploma Study Program in determining the program that suits the needs of students in completing their final studies, which is based on predictions of initial data on the students' basic competencies of Information System Diploma Program. The program that had been run showed significant results. Before the program was run, the timely graduation rate was only 67.48% in 2017. Meanwhile, after the program was run, the timely graduation rate reached 85.04% in 2019. This means that there was an increase of 26%.

This research was conducted locally and only applies to Information System Diploma Study Program. For further research, it can be improved through larger student data from various universities that have the same major and use the latest Information System Curriculum approach, namely IS 2020 and The New SFIA Framework.

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**Declaration of Conflicting Interests**

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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