MINISTRY OF EDUCATION AND TRAINING

VIETNAM ACADEMY OF SCIENCE AND TECHNOLOGY

GRADUATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

HUYNH THI NGOC CAM

APPROACHING MACHINE LEARNING TO SELECTING AND VISUALIZATION TO TRAINING THE MEMBERS OF TEAM

SUMMARY OF DOCTORAL THESIS ON COMPUTER SCIENCE

Code: 9 48 01 01

Ha Noi - 2025

The thesis is completed at: Graduate University of Science and Technology, Vietnam Academy of Science and Technology

Advisor:

Assoc.Prof. Tran Vinh Phuoc, Ph.D., Ho Chi Minh City University of Natural Resources and Environment

Reviewer 1: .....

.....

Reviewer 2: .....

.....

Reviewer 3: .....

.....

The thesis was defended with the board assessing doctoral dissertation at Graduate University of Science and Technology, Vietnam Academy of Science and Technology at . . . . . ., date……. . . . . .

The thesis may be referred at:

1. The library of Graduate University of Science and Technology
2. Vietnam National Library

I. INTRODUCTION

1. Motivation

Annually, the Ministry of Education and Training of Vietnam organizes the national excellent student exam for high school students in subjects such as Informatics, Mathematics, Physics, Chemistry, Biology, etc.. Each high school forms a team for each subject and assign a teacher as the coach to participate in the exam. The coach is responsible for selecting teamers (team members) and providing intensive training according to the exam requirements. Facing the school's achievement demands, coaches encounter challenges:

- How to understand the competency factors necessary for an examinee participating in a national excellent student exam with respect to subject?
- How to correctly select excellent students with the capacity to meet national excellent student exam's requirements?
- Which method to enhance the teamers' capacity to meet the national excellent student exam's requirements?

Guided-discovery learning is a suitable approach for teamer training, as teamers need to be developed independence in thinking and learning activities to participate in the national excellent student exam.

2. Thesis Objectives

General Objective: Setting up the model selecting informatics teamers and training them to participate in the national excellent student exam with the expectation of winning multiple awards, in the light of machine learning and data visualization approaches in computer science.

Specific Objectives:

- Analyzing the competency factors of winners and nonwinners to mathematically model each examinee as a mathematical

vector in a multi-dimensional space, where each dimension represents a competency feature variable.

- Developing algorithm and process selecting excellent students for the high school informatics team participating in the national informatics excellent student exam.
- Setting up a guided-discovery learning model using visualization techniques and evaluating the efficiency of each lecture for the team and the teacher.

3. Research Subjects of the Thesis

- Competency of examinees who have participated in the national excellent student exams in informatics.
- Educational Data on student competency.
- Machine learning approaches to mining educational data.
- Learning theory and discovery learning model.
- Principles acquiring and storing new human (student) knowledge.

4. Research Scope of the Thesis

- Research data relating to winners and nonwinners of national informatics excellent student exams.
- Student's competency features are composed of learning features and non-learning features.
- Guided-discovery learning model - pilot application for a high school informatics team.

5. Research Methods

- *Analysis–Synthesis Method:* The analysis-synthesis method is applied to analyze the competency of each student as a multi-variable competency feature vector, and to design the lecture for students according to the visually-guided-discovery learning model.

- *Mathematical Modeling Method:* The mathematical modeling method is applied to model the student's competency as a competency feature vector in multi-dimensional competency space.
- *Machine Learning Method:* The thesis applies supervised machine learning and proposes the Winner-domain algorithm to classify candidates and find out students most likely to win national awards.
- *Decision Tree Method:* The thesis applies the decision tree method with the cosine similarity algorithm to decide to select the most likely students for team from the candidates selected by Winner-domain.
- *Mathematical Method:* The mathematical method is applied to set up dataset.
- *Programming Method:* The Python software is used to set up the programs applied to the research.
- *Survey Method:* The survey method is applied to design questionnaire and collect data by Google Forms.
- *Experimental Method:* The experimental method applied the algorithms of Winner-domain, Winner-cosin and decision tree to select teamers of a high school.

6. Contributions of the Thesis

6.1. The results of the content 1:

- The approach to designing simply qualitative survey questions easy to answer.
- The approach to forming competency feature variables and quantifying qualitative survey replies.
- The dataset of examinees who have participated in recent national informatics exams.

6.2. The results of the content 2:

- The Winner-domain approach to defining the competency domain of winners in a multi-dimensional competency space.
- The decision tree approach with the Winner-cosin algorithm enables to decide to select teamers from candidates of the competency within good Winner-domains.

6.3. The results of the content 3:

- The thesis formed a visually-guided-discovery learning model and proposed an approach to evaluating its efficiency for each lecture by instructor**.**

7. Structure of Thesis

The thesis is designed with an introduction, five content chapters, and a conclusion. The list of the author's published works, the list of references, and the experimental appendix are edited at the end of the thesis.

- *Introduction:* The thesis introduces the context leading to the topic with 3 challenges to research.
- *Chapter 1:* The chapter presents the overview of related works on educational data mining.
- *Chapter 2:* The chapter presents the theoretical basis of discovery learning.
- *Chapter 3:* The chapter designs the examinee competency dataset according to the process: analysing competency feature → mathematical modeling of competency → designing survey questions → collecting qualitative replies → quantifying replies → quantifying competency variable sets of the competency space and quantifying competency features of each surveyed individual → setting up dataset. The thesis edited qualitative questionnaires and proposed reply matrix, reply 3D cube approaches to quantify competency feature variables from qualitative replies by examinees.

- *Chapter 4:* The chapter presents the Winner-domain approach to form potential domains (good domains) and the decision tree with the cosine similarity algorithm (Winner-cosine) to select candidates of competency features within good potential domains.
- *Chapter 5:* The chapter presents the visually-guided-discovery learning approach to training teamers.
- *Conclusion:* The section summarizes the author's main contributions and future development directions.

THESIS CONTENT

CHAPTER 1. OVERVIEW OF RELATED WORKS ON EDUCATIONAL DATA MINING

The related works are the research on students' competency data, algorithms of separating objects into groups by their features. The related works are composed of the following topics:

- Educational data.
- Educational data mining approaches as support vector machine (SVM), decision tree, K-mean clustering, data processing.

CHAPTER 2. THEORETICAL BASIS OF DISCOVERY LEARNING

The thesis presents the theoretical basis of education method, the concepts of learning and discovery learning, models and methods of discovery learning, the characteristics of discovery learning and guided-discovery learning. Finally, the thesis studies the theory of human information/knowledge acquisition to propose the model of visually-guided-discovery learning at the chapter 5.

CHAPTER 3. DATASET OF EXAMINEES' COMPETENCY

3.1. Introduction

3.2. Competency Factors of Examinees

3.3. Questionnaire

3.4. Data collection

3.5. Data Pre-processing

3.6. Quantifying the value sets of competency features in competency space.

3.7. Quantifying the non-learning feature components of examinees' competency vectors.

3.8. Dataset of examinees' competency having participated in national excellent student exams.

3.9. Conclusion of chapter 3

Summary of Chapter 3 Main Contents

The datasets of educational data for research on education have to be suitable for research objectives, educational environment, research objects, and user of results. Accordingly, the educational researches do not share dataset, each research must design a special dataset suitable for the number of variables and instances.

Competency features of the examinees participating in national excellent student exams are the factors impacting on the results, including learning and non-learning competency. The thesis analyzed competency factors into simple, easy, and quick-to-answer qualitative survey questions. The competency of each surveyed person is modeled as a multi-dimensional competency vector, each dimension as a variable corresponds to a qualitative reply in the survey.

The thesis collected and pre-processed replies, proposed the reply matrix (Table 3.5) and reply 3D cube (Figure 3.2) approaches to quantify the competency vectors in the multi-dimensional competency space. The dataset is set up from the processed replies, where each

instance is labelled with winner or non-winner. The process setting up dataset is presented as the figure 3.1

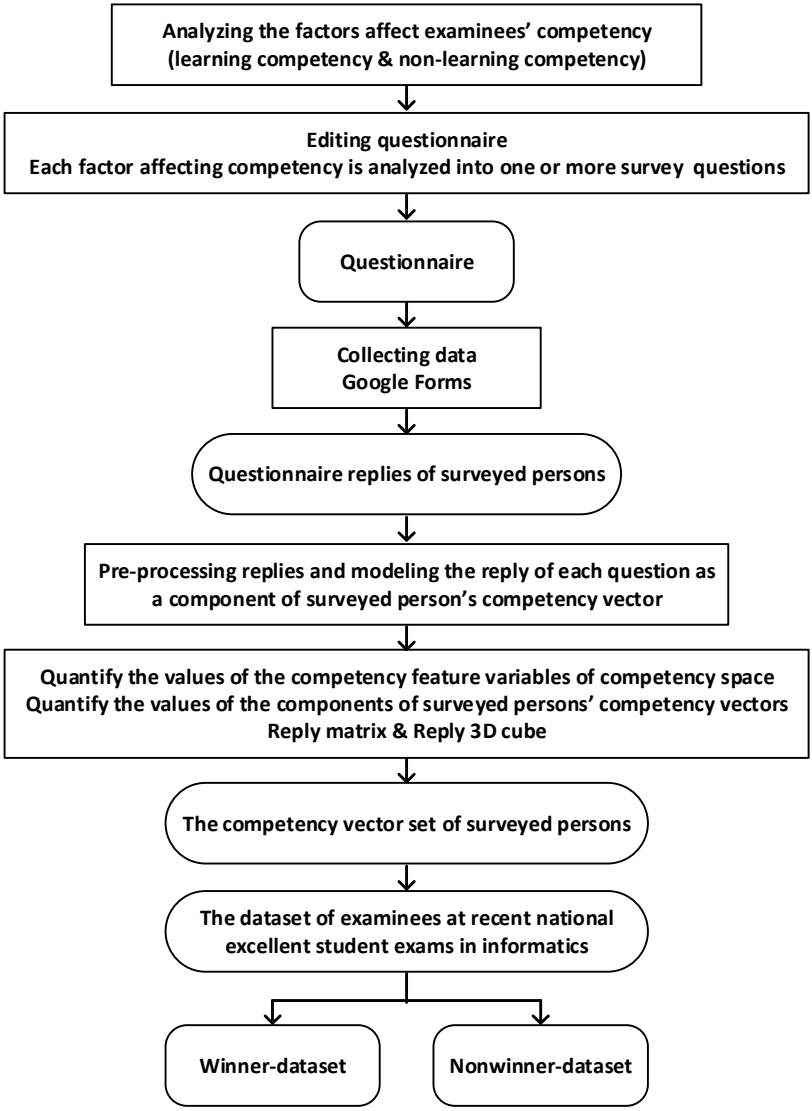

Figure 3.1 The process setting up the dataset of the thesis

Table 3.5. Reply matrix of the features of non-learning competency s=19,20,..,40 of surveyed person m| m=1,2,..,M.

Question 19	a_{19}^m	b_{19}^m	c_{19}^m	d_{19}^m	e_{19}^m	f_{19}^m			
Question 20	a_{20}^m	b_{20}^m	c_{20}^m	d_{20}^m					
Question 21	a_{21}^m	b_{21}^m	c_{21}^m	d_{21}^m	e_{21}^m	f_{21}^m	g_{21}^m	h_{21}^m	
Question 22	a_{22}^m	b_{22}^m	c_{22}^m	d_{22}^m	e_{22}^m				
Question 23	a_{23}^m	b_{23}^m	c_{23}^m	d_{23}^m					
Question 24	a_{24}^m	b_{24}^m	c_{24}^m						
Question 25	a_{25}^m	b_{25}^m							
Question 26	a_{26}^m	b_{26}^m	c_{26}^m						
Question 27	a_{27}^m	b_{27}^m	c_{27}^m	d_{27}^m	e_{27}^m	f_{27}^m	g_{27}^m	h_{27}^m	
Question 28	a_{28}^m	b_{28}^m	c_{28}^m	d_{28}^m					
Question 29	a_{29}^m	b_{29}^m							
Question 30	a_{30}^m	b_{30}^m							
Question 31	a_{31}^m	b_{31}^m							
Question 32	a_{32}^m	b_{32}^m	c_{32}^m	d_{32}^m	e_{32}^m	f_{32}^m	g_{32}^m	h_{32}^m	i_{32}^m
Question 33	a_{33}^m	b_{33}^m	c_{33}^m	d_{33}^m	e_{33}^m	f_{33}^m	g_{33}^m	h_{33}^m	
Question 34	a_{34}^m	b_{34}^m							
Question 35	a_{35}^m	b_{35}^m	c_{35}^m	d_{35}^m					
Question 36	a_{36}^m	b_{36}^m	c_{36}^m						
Question 37	a_{37}^m	b_{37}^m	c_{37}^m	d_{37}^m					
Question 38	a_{38}^m	b_{38}^m	c_{38}^m	d_{38}^m					
Question 39	a_{39}^m	b_{39}^m	c_{39}^m	d_{39}^m	e_{39}^m				
Question 40	a_{40}^m	b_{40}^m	c_{40}^m	d_{40}^m	e_{40}^m				

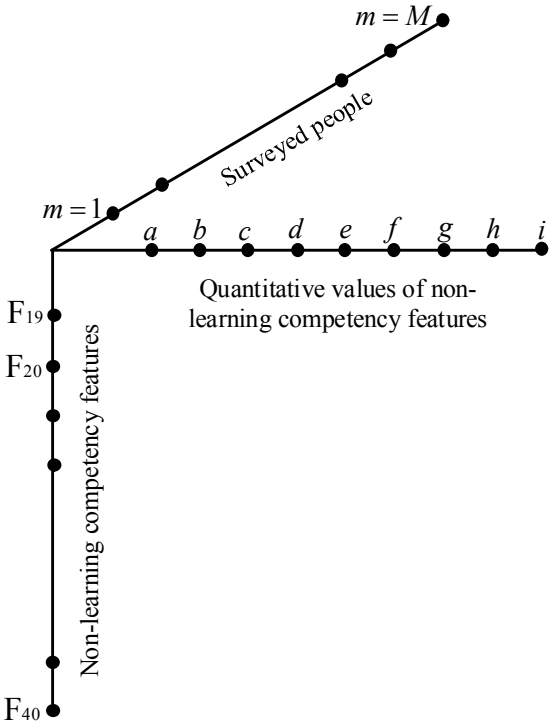

Figure 3. 2. Reply 3D cube to quantify the values of non-learning feature variables $F_{19}, F_{20}, .., F_{40}$

Table 3.7. Dataset model

Surveyed people	f_1	..	f_{18}	f_{19}	..	..	f_{40}
m = 1	f_1^1						f_{40}^1
m = 2							
..							
..							
m = M	f_1^M						f_{40}^M

Conclusion of the chapter 3

The thesis proposed the approach to setting up smart dataset suitable for forming the team participating in excellent student exams of various awards. The smart dataset enables the process setting up the datasets on the competency of examinees participating in excellent student exams in various subjects. The process may be applied to form teams for various disciplines.

CHAPTER 4. MACHINE LEARNING APPROACH TO SELECTING MEMBERS FOR TEAMS PARTICIPATING EXCELLENT STUDENT EXAMS

4.1. Introduction
4.2. Related works
4.3. Problem description
4.4. Experiment and estimation: school years 2023-2024, 2024-2025.
4.5. Conclusion of the chapter 4

Summary of Chapter 4 Main Contents

Research Question

Which candidate is likely to win award?

Problem Description
Input:

- The set of winners, winner-dataset $W=\{w_1,..,w_N\}$. Each winner w_n is represented as a mathematical vector in competency space of S dimensions.
- The set of examinees participated in the exam but not win award, nonwinner-dataset $U=\{u_1,..,u_M\}$. Each nonwinner

u_m is represented as a mathematical vector in competency space of S dimensions.

- The set of candidates $X = \{x_1,..,x_L\}$ who want to become teamer. Each candidate x_l is represented as a mathematical vector in competency space of S dimensions.

Output:

- The set of the candidates are selected as teamers $Y_{team} = \{y_1,..,y_{K\,team}\}$

Winner-domain approach. The characteristics of winner-domain (Figure 4.1):

- *Centroid* w_c^p *of training set:* $w_c^p = [f_{1.c}^p;..;f_{s.c}^p;..;f_{S.c}^p]$
- *Radius* R^p *of training set*: $R^p = d_{max}^p(w_c^p, w_i^p), \forall i$

where $d_{c.i}^p \equiv d(w_c^p, w_i^p) = \sqrt{(f_{1.c} - f_{1.i})^2 + .. + (f_{S.c} - f_{S.i})^2}$

- *Directional angle* θ^p *of training set* V^p:

$$\cos\theta_{c.i}^p = \frac{w_c^p.w_i^p}{|w_c^p||w_i^p|} = \frac{f_{1.c}^p.f_{1.i}^p + .. + f_{s.c}^p.f_{s.i}^p + .. + f_{S.c}^p.f_{S.i}^p}{\sqrt{(f_{1.c}^p)^2 + .. + f_{S.c}^p)^2}\sqrt{(f_{1.i}^p)^2 + .. + (f_{S.i}^p)^2}}$$

The Winner-domains $D_k^p(w_c^p, R_k^p, \theta_k^p)$ with $R_k^p = \alpha_k.R^p$ are evaluated by the coefficients *TP, FP, FN* of the unnormalized confusion matrix. The Winner-domains with high *TP*, low *FP*, low *FN*, and not including any nonwinner $u_m, \forall u_m \in U \,|\, m=1,..,M$ are convex domains, called good Winner-domain $Dg^q, u_m \notin Dg^q | m=1,..,M | q=1,2,..$

- Centroid w_c^p, and Training set $V^p = \{w_1,..,w_1\} \,|\, p=1,2,..$
- Radius $R_k^p = \alpha_k.R^p$ với $\alpha_k < 1 \,|\, k = 1,2,..$

- Trending angle $\theta_k^p \le \theta^p = (\theta_{c.i}^p)_{\max} \mid \forall i, i = 1,..,I_k^p$ với I_k^p is the number of instances of the Winner-domain $\mathrm{D}_k^p \mid k = 1,2,..$

The complexity of Winner-domain algorithm is calculated by:

$$O(P.K.(N+M).S)$$

$$T(n)=O(P.K.(N+M).S)$$

Table 4. 1. Unnormalized confusion matrix

Testing data set	Conclusion: Win (column 1 of matrix)	Conclusion: Non win (column 2 of matrix)
Win class (line 1 of matrix) $\mathrm{V} = \{\mathrm{v}_i, i = 1,..,I\}$	TP : The number of instances $\mathrm{v}_i, \mathrm{v}_i \in \mathrm{V}$ are predicted: TRUE POSITIVE	FN: The number of instances $\mathrm{v}_i, \mathrm{v}_i \in \mathrm{V}$ are predicted FALSE NEGATIVE (missed)
Non win class (line 2 of matrix) $\mathrm{U} = \{\mathrm{u}_j, j = 1,..,J\}$	FP : The number of instances $\mathrm{u}_j, \mathrm{u}_j \in \mathrm{U}$ are predicted FALSE POSITIVE	TN : The number of instances $\mathrm{u}_j, \mathrm{u}_j \in \mathrm{U}$ are predicted TRUE NEGATIVE

Winner-cosin approach

The cosin-similarity:

$$\mathrm{CosinSimilarity}(\mathrm{x}_l, \mathrm{w}_n) \equiv \cos\theta_{l.n} = \frac{\mathrm{x}_l.\mathrm{w}_n}{|\mathrm{x}_l||\mathrm{w}_n|} = \frac{\mathrm{f}_{1.l}.\mathrm{f}_{1.n} + .. + \mathrm{f}_{s.l}.\mathrm{f}_{s.n} + .. + \mathrm{f}_{S.l}.\mathrm{f}_{S.n}}{\sqrt{(\mathrm{f}_{1.l})^2 + .. + \mathrm{f}_{S.l})^2}\sqrt{(\mathrm{f}_{1.n})^2 + .. + (\mathrm{f}_{S.n})^2}}, \forall n$$

The total complexity of Winner-cosin algorithm: $O(L.(S+P)+K.N.S+K.\log K)$ with K_{team} □ L and K_{team} □ N

Conclusion of the chapter 4

Applying machine learning, the chapter 4 formed the schema of the decision selecting candidates for the team based on the model of student's competency as multidimensional vector. The thesis proposes

the approaches to evaluating the similarity of the candidates with winners of few recent exams:

- The approach of Winner-domain to evaluating the similarity of competency feature magnitudes.
- The approach Winner-cosin with cosinsimilarity algorithm to evaluating the similarity of the competency feature trend.

Because of the number of candidates is very big in comparison with the number of necessary teamer, the thesis does not label each candidate. The thesis applies the strategy of "Better to exclude than wrongly include" to select the candidates more likely to win award for team. The work was experimentally applied at a high school with good results in comparison with the years in the past.

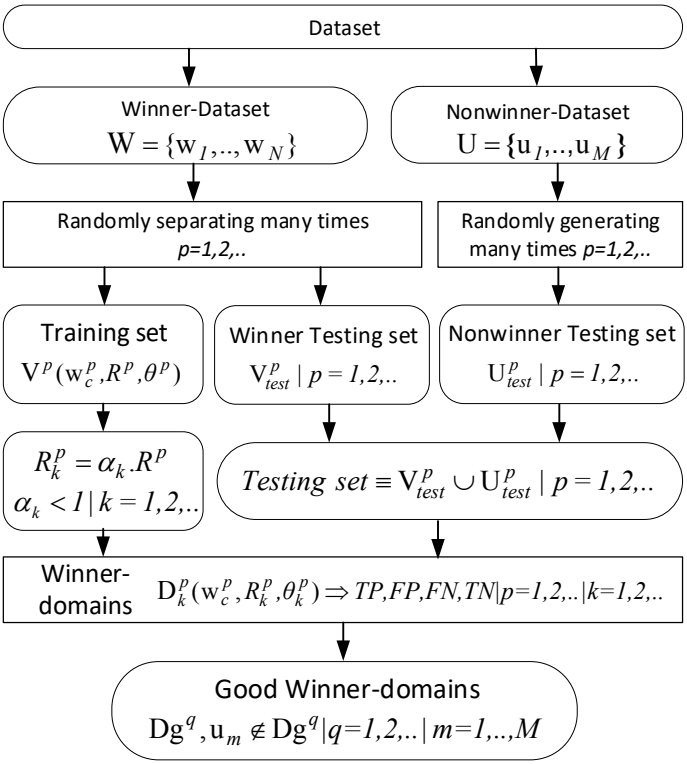

Figure 4.1. Process to form Good Winner-domains

Table 4.31. The method of the thesis is experimentally compared with the traditional method.

School years	The number of teamers participating in national excellent student exams in informatics	Teamers are selected with traditional method					Teamers are selected with the model of Winner-domain combining with Winner-cosin					The number of winners	Note
		Quantity (qt)	Winner		Nonwinner		Quantity (qt)	Winner		Nonwinner			
			qt	Ratio %	qt	Ratio %		qt	Ratio%	qt	Ratio %		
2019-2020	6	6	0	0%	6	100%						0	
2020-2021	6	6	1	16.67%	5	83.33%						1	
2021-2022	6	6	3	50%	3	50%						3	
2022-2023	6	6	1	16.67%	5	83.33%						1	
2023-2024	10	10	5	50%	5	50%	5	5	100%	0	0%	5	Model of Winner-domain combining with Winner-cosin
2024-2025	10	10	6	60%	4	40%	6	6	100%	0	0%	6	Model of Winner-domain combining with Winner-cosin

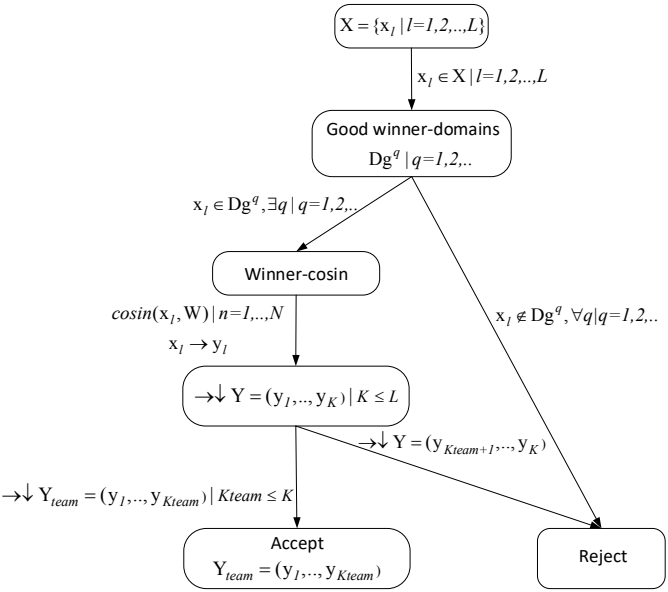

Figure 4.2. Decision tree to select teamers

Table 4.32. Comparing the results of the model of Winner-domain combining with Winner-cosin selecting teamers with the model of Random Forest predicting examinee's result in the national excellent student exams in informatics in academic years 2023-2024 and 2024-2025

Criteria for comparing	**2023-2024**		**2024-2025**	
Exams	The model of Winner-domain combining with Winner-cosin	The model of Random Forest	The model of Winner-domain combining with Winner-cosin	The model of Random Forest
{Teamers were selected by traditional model} = {Candidates to input into the models of computer science}	10		10	

The number of candidates are selected as teamers or predicted as winners.	05	08	06	08
The number of teamers really win awards	05		06	
The ratio of true selection of winners or true prediction of winners: *TPR*	100%	62.55 %	100%	75.0 %
The ratio of false selection of winners or false prediction of winners: *FPR*	0%	0.6%	0%	0.5%
The ratio of false nonwinner: *FNR*	0%	0%	0%	0%
The ratio of true estimation or true prediction of nonwinner: *TNR*	1%	0.4%	1%	0.5%

5. APPROACHING VISUALLY-GUIDED-DISCOVERY LEARNING TO TRAINING TEAM

5.1. Guided-discovery-learning. Guided-discovery-learning is developed from the theory of discovery learning to apply for educational institutions with the model of 3 components: learners, learning documents, instructors.

5.2. Visually-guided-discovery-learning. Visually-guided-discovery-learning is developed from the model of guided-discovery-learning with visual lecture, structured as the figure 5.1 and 5.2.

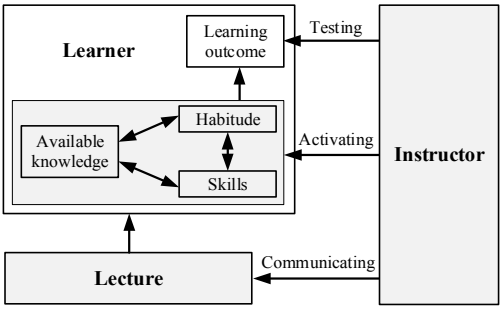

Figure 5.1. The structure of a visually-guided-discovery-learning system.

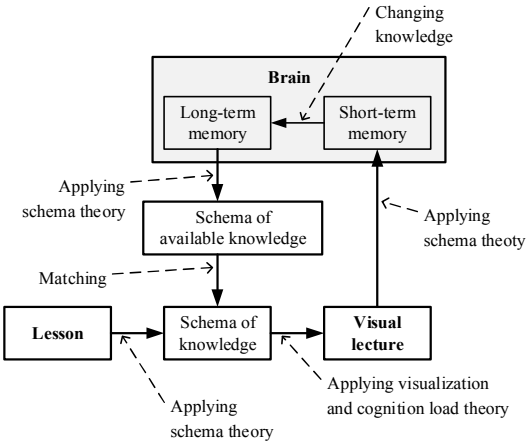

Figure 5.2. The information flow of learners' learning process in visually-guided-discovery-learning system.

5.3. Evaluating visually-guided-discovery-learning system

$$E = \frac{O + K + S + A + M + V + P}{C + T} \times \frac{20}{7}\%$$

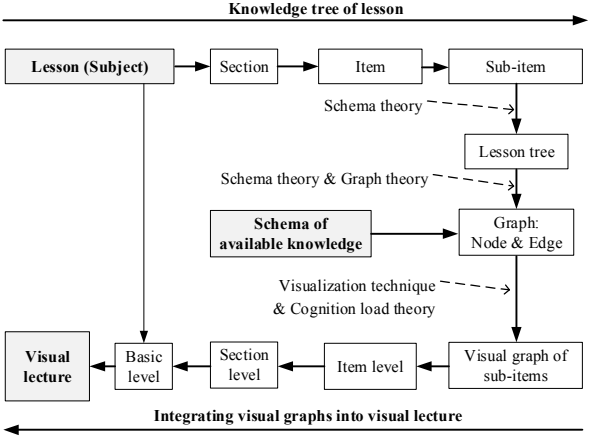

Figure 5.3. The process to design visual lecture according to the lesson.

E: The efficiency of visual lecture

O: The knowledge which the learner added to long-term memory after each lecture.

K: The available knowledge of the learner.

S: The skills of the learner

A: The habit of the learner.
M: The matching of lecture with learner' available knowledge.
V: The visual characteristics of the lecture.
P: The pedagogic competence of the instructor
C: The complexity of the lesson.
T: The time necessary to acquire and add new knowledge to the learner's long-term memory.

5.4. Applying the method of visually-guided-discovery learning to train an informatics team. The informatics team is trained to solve exam questions according to the process: (1) Identifying and understanding the questions; (2) Planning how to solve; (3) Developing the plan; (4) Checking results.

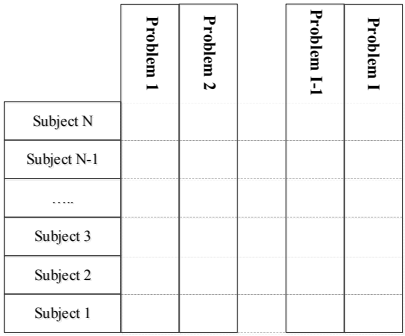

Figure 5.4. The process to design visual lecture according to problem.

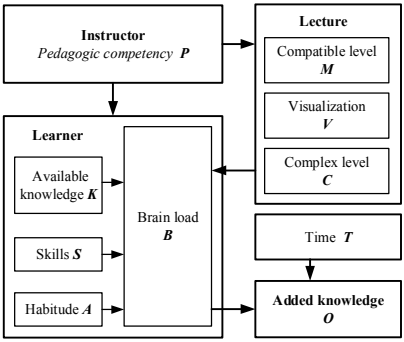

Figure 5.5. The model to evaluate the efficiency of the visually-guided-discovery system for a lecture.

The visually-guided-discovery-learning system is evaluated by the efficiency of each lecture with respect to each learners' group and instructor by comparing learners' achievement knowledge with mobilized brain load and learning time.

Conclusion of the chapter 5

The thesis proposed the model of visually-guided-discovery model combining with the characteristics of collaborative learning and problem learning. The model of visually-guided-discovery learning is in accordance with not only the development of society, data and information source, internet, but also necessary to train informatics team.

CONCLUSION

The thesis achieved the following results:

1. ***Dataset.*** *The thesis formed the dataset of the competency of examinees who have participated in the exam of national excellent students in informatics, including winners and nonwinners.*

The thesis set up the competency feature vector model of examinees, comprising learning features and non-learning features. The approach of reply matrix and reply 3D cube are proposed to quantify the sets of competency feature variables of competency space and the competency feature components of surveyed person. The result is 2 datasets: the dataset 2024 comprised 221 examinees (120 winners and 101 nonwinners) who participated in national informatics excellent student exam in school years 2020-2021, 2021-2022, 2022-2023; the dataset 2025 comprised 497 examinees (360 winners and 137 nonwinners) who participated in national informatics excellent student exam in school years 2021-2022, 2022-2023, 2023-2024.

The process setting up the dataset of the thesis is smart, suitable for the Winner-domain and Winner-cosin approaches and adaptive with examinees of national excellent student exams. The smart dataset may

easily change the number of instances, update the number and contents of data variables according to the request of exam.

2. ***The model of Winner-domain combining with Winner-cosin.*** *The thesis formed the model selecting excellent students for informatics team of a high school to participate in national excellent student exam in informatics by combining the proposed algorithms of Winner-domain and Winner-cosin.*

In the light of the philosophy "person near ink is darkened, person near light is brightened" and the strategy "Better to exclude than wrongly include", the thesis formed the model combining the algorithms of Winner-domain and Winner-cosine, proposed by the thesis, to select members of informatics team. The thesis was experimentally applied in school years 2023-2024 and 2024-2025.

3. ***The model of visually-guided-discovery learning.*** *The thesis proposed the model of visually-guided-discovery learning.*

The thesis combined discovery learning model with collaborative learning and project learning models, … and the theories of graph, human cognition load in the process acquiring and storing knowledge, along with visual technique to form the process and the method editing visual lecture for the model of visually-guided-discovery learning. The thesis also formed the mathematical model to evaluate the efficiency of each visual lecture.

The thesis is continuously researched to update the instances of new examinees and develop competency feature variables in accordance with other exams.

PUBLISHED ARTICLES RELATING TO THE THESIS

[CT.1] **Cam Ngoc Thi Huynh**, Hiep Van Nguyen, Phuoc Vinh Tran, Diu Ngoc Thi Ngo, Trung Vinh Tran, and Hong Thi Nguyen, "An Approach to Selecting Students Taking Provincial and National Excellent Student Exams," in Context-Aware Systems and Applications, C. V. Phan and T. D. Nguyen, Eds. no. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, 2023, vol 475. Springer. pp.156–161 ISBN 978-3-031-28815-9 (Scopus).

[CT.2] **Cam Ngoc Thi Huynh**, Phuoc Vnh Tran, and Trung Vinh Tran, "The Approach of Winner-domain to Selecting Members for High School Team Participating in National Excellent Student Exam," Mobile Networks and Applications, 2024, Volume 29, Issue 1, pp. 306-313. (SCIE, Q2 / 2024), (Scopus).

[CT.3] **Cam Ngoc Thi Huynh**, Anh Van Thi Tran, Tha Thi Bui, Hong Thi Nguyen, and Phuoc Vinh Tran, "Applying Guided Discovery Learning to Enhance the Achievement of Information Technology Team," Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. Context-Aware Systems and Applications, 2024, vol 579, pp. 186–196 Springer, Cham.ISBN: 978-3-031-58877-8 (Scopus).

[CT.4] **Cam Ngoc Thi Huynh**, Hong Thi Nguyen, Phuoc Vinh Tran, “Efficiency of Visually-Guided Discovery-Learning System for High School”, International Conference on Energy, Infrastructure and Environmental Research (EIER 2025), E3S Web of Conferences 626, 04002 (2025), eISSN: 2267-1242. (Scopus).