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Development of Students' Critical Thinking in the Context of Information Security

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DEVELOPMENT OF STUDENTS' CRITICAL THINKING IN THE CONTEXT OF INFORMATION SECURITY

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Abstract. The problem of students' critical thinking development in the context of information security becomes important in international and national educational policies as a means of fostering active citizenship and in turn sustainable development. The purpose of the given research is to introduce theoretical substantiation and experimental approbation of students' critical thinking development in the context of information security. The skills of critical thinking help students to cope with the bulk of information they daily receive. However, there is still no conventional methodology for critical thinking development in university students. In our study we suggest possible ways to develop critical thinking in university students via introducing some special courses into the curriculum, and consider the results of the experimental study conducted on the basis of two Ukrainian leading universities. In order to improve the students' skills of critical thinking the author suggested implementing the special course "The specifics of students' critical thinking in the context of information security", and an optional distance course on optimization of students' critical thinking on the background of information and communication technologies. After the implementation of the suggested courses the indicators of students' critical thinking development showed positive changes and proved the efficiency of the special courses as well as the general hypothesis of the study.

1 Problem statement

In the course of substantiating the terms of information security, let us mention the interpretation of the "critical thinking" concept. It is a type of human intellectual activity characterized by high level of perception, understanding, and objective approach to the surrounding information field.

We believe that the modern globalization processes and the rapid development of information technologies in the multicultural world have led to negative consequences for humanity, and also affect the mission of higher educational institutions. For that reason, these days the mission of modern universities is to develop the information culture of students in order that they could critically evaluate the events in the world and appropriately respond to them. Accordingly, a critically thinking student is able to adequately analyze information, verify its accuracy, data contradictions, select and evaluate arguments to prove.

It should be noted that "critical thinking" concept is quite common in both psycho-pedagogical periodicals, and technical publications. Moreover, there is no unique interpretation of "critical thinking" concept because it is multifaceted, so each researcher is focused on a particular aspect of the concept. An active study of this concept can be found in the context of foreign language learning. The explanation for this phenomenon is quite simple. Such strong interest of foreign language methodologists can be explained by the fact that the first scientific researches of this concept belong to foreign scientists and researchers. The definitions given by different authors have some differences and depend on their own approaches to the formation and development of critical thinking (D. Dewey, A. Fisher, B. Blum, R. Mayer, P. Freire).

2 Analysis of recent studies

The researches of critical thinking began in the 1960s. Researchers made attempts to explain critical thinking via philosophical and psychological approaches. Paul (1989) in his studies made attempt to give a definition for critical thinking. He argued that critical thinking included skills, such as spotting conclusions, examining premises, forming conclusions and diagnosing fallacies [1]. Consequently, he put forward the idea that critical thinking may be regarded as disciplined, self-directed thinking which exemplifies perfection of thinking appropriate to a particular mode or domain of thinking [1]. Bowell and Kemp (2002) published a concise guide to critical thinking, where they introduced and discussed the main concepts related to critical thinking, gave examples and provided exercises and techniques of how to become a critical thinker. The researcher Wright regarded the problem of critical thinking in the context of the social world of the young learner (2002), and later Giancarlo, Blohm, and Urdan (2004) studied the issue of secondary students' disposition toward critical thinking. Australian scholar Lloyd researched critical thinking in the context of higher education (2010). Lai (2011) gives a literature review on critical thinking; she explores the ways in which critical thinking has been defined by researchers, investigates how critical thinking develops, learns how teachers can encourage the development of critical thinking skills in their students, and reviews best practices in assessing critical thinking skills [6]. Turkish researcher Karakoç (2016) regarded the significance of critical thinking ability in terms of education process and the importance of thinking critically for a student who attends any education programme [7]. However, the problem of students' critical thinking development in the

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context of information security has not been the subject for scientific discussion yet.

The purpose of the article is to introduce theoretical substantiation and experimental approbation of students' critical thinking development in the context of information security.

3 Methods of research

To achieve the goal of the given study we have used such theoretical methods of research as analysis of philosophical, psychological and pedagogical literature on the problem of research in order to determine the conceptual and categorical apparatus and to consider the state of theoretical and practical elaboration of the problem of students' critical thinking development. Also we have applied the following empirical methods: observation, interviews, questioning, testing to diagnose the level of students' critical thinking development; pedagogical experiment to test the effectiveness of the proposed educational conditions; statistical methods for processing the results of experimental work.

4 The results and discussion

Despite the generally accepted concept of "critical thinking", there is still no conventional methodology for critical thinking development in university students, so we shall suggest and experimentally test the methods and technologies for its testing. Presently, it is essential to organize and summarize the accumulated experience of scientists as to this concept.

Scientists suggest several stages of students' critical thinking development. Particularly, in the first stage the students' attention is focused on the problem, and they get interested in the topic under discussion; the second stage involves setting the goal and task of the lesson, checking the previously learned educational material; the third stage provides practical mastering of the educational material, achievement of the goal set; the last stage (reflection) involves analysis of the lesson, advantages and disadvantages in the classroom activity, elimination of possible mistakes in future educational activity [8].

More frequently, critical thinking is regarded as a person's ability to think independently, to analyze information; the ability to realize mistakes or logical violations in partner's statements; give reasons for their thoughts, change them if they are wrong; the presence of a mental part of skepticism and doubt; striving to find optimal solutions; courage, commitment to principle, bravery in defending their position; open-mindedness to different views [9].

In the course of scientific research, many scholars try to identify the key factors for critical thinking development in university students. Consequently, researchers believe that the major requirement is that the information should not be fully provided to the students, teachers should create conflicting and problematic situations in certain disciplines, which will activate students' critical thinking. Such strategy motivates students to find new information that is not sufficient for their complacency. The specifics of the educational discipline can also influence the development and consolidation of skills which teach students to logically build the methodology of gaining scientific knowledge in their professional field [10].

In the course of professional training a teacher should demonstrate a tolerant attitude towards any student's position, since such a position is personal and most vulnerable for the further personal development of the student. A positive attitude towards dissidence from both the teacher and the students is the principal condition for students' critical thinking development.

The most important and fundamental factor is to provide students with the basic necessary methods for the development of critical thinking, that is, to acquaint students with the basic thinking operations that inspire critical thinking [11].

In our opinion, the background of critical thinking is the pedagogical educational activity of students and the development of such skills as: analysis, synthesis, evaluation, comparison, correlation, etc. Students have to set themselves a series of goals to overcome difficulties, develop an improved working plan and realize that they can enhance their professional competence by means of internal resources [12].

The scholars in the field of education have also participated in discussions about critical thinking. Benjamin Bloom and his associates are included in this category. Their taxonomy for information processing skills (1956) is one of the most widely cited sources for educational practitioners when it comes to teaching and assessing higher-order thinking skills. Bloom's taxonomy is hierarchical, with "comprehension" at the bottom and "evaluation" at the top. The three highest levels (analysis, synthesis, and evaluation) are frequently said to represent critical thinking [13].

The term "taxonomy" means the classification and organization of objects, based on natural interrelationship, which is used to describe the categories arranged in order of their increasing complexity. One of the main principles of taxonomy is that it should be an effective tool, both in learning and evaluating learning outcomes. Bloom's taxonomy is presented in table 1.

In the context of our research we are interested in the highest possible level of critical thinking development (4, 5, 6 levels in the Table 1), namely: analysis, synthesis, evaluation of information received. Consequently, the fourth level (analysis of the information received) involves such students' activity as dividing information into related parts. The activity of the tutor/curator includes the following: he accompanies, teaches, helps to make attempts, and finds the sources of information.

As a result, students should adequately analyze, arrange, systematize, compare, establish correlation (between words, parts of a whole), contrast, distinguish, differentiate, separate parts, draw (conclusions), organize, ask questions, relate, and separate.

At the fifth level (synthesis) students should combine information to create a new entity. The activity of the curator in the course of thinking skills development is to

expand, evaluate, reflect and influence the activities of students.

Table 1. Bloom's taxonomy

Thinking Skills	***Definition***	***Curator or tutor activity***	***Students' activity***
Evaluation	Evaluation based on criteria	Evaluation based on criteria	Evaluate, assess, argue, give evidence, determine give preference; make choice, support, draw conclusions,
Synthesis	Combining information to create a new entity	Expands, evaluates, reflects, influences	Systematize, combine, connect, create, design, invent redistribute, modernize, suggest hypotheses
Analysis	Dividing information into related parts	Accompanies, teaches, assists, tries to find the sources of information	Analyze, arrange, systematize, compare, establish correlation organize, ask questions, relate, separate
Usage	Using of concepts, ideas in new situations	Observes, draws attention, promotes, helps, criticizes	Use, consume, calculate, demonstrate, give examples, interpret, relate, make a list, describe in general terms
Understand-ing	Understand ing	Verifies, correlates, demonstrates	Discuss, recognize, retell, explain, make messages, demonstrate examples
Knowledge	Identificati on and retelling	Tells, shows, manages, points	Memorize, learn, master, recognize, remember, name; cite, identify, register, put to a certain category

As a result, students must learn to systematize, combine, connect, create, design, invent, construct, generate (principles, rules), integrate, enlarge, elaborate, transform, modify, correct, arrange, work up, rearrange, redistribute, modernize, use instead of something, suggest hypotheses, etc.

The highest level (evaluation) gives the student an opportunity to determine the value based on criteria. In this case, the activity of the curator/tutor is accompanying, because he clarifies, concludes, admits, recognizes, agrees, leads to agreement as to one or another piece of information.

As a result students should evaluate, assess, argue, give evidence, determine (rate, significance, benefit, harm), give preference; make choice, support (requirements, standards, criteria), draw conclusions, persuade, make decisions, uphold, justify (actions, deeds, etc.), judge, attribute (class, rank), become arbitrators, anticipate, predict, distribute places, provide recommendations, corroborate evidence, argue for (something/somebody).

Let us proceed directly to the detailed characteristics of each criterion of information culture of students in the context of information security.

Table 2. Criteria and indicators of students' critical thinking development in the context of information security.

Criteria	**Indicator**
Motivational	1) motivation to search, retrieve and critically analyze certain information; 2) constant motivations to achieve success, self-fulfillment in professional activity ;
Content-related	3) basic knowledge about information resources, information systems, information technologies, informatization of society; 4) the ability to independently create and develop new knowledge based on the information received ;
Activity-based	5) the ability to operate following the sequence of actions and complete awareness of the actions for critical analysis of new information ; 6) information insight, the ability to plan and predict possible consequences based on the information received;
Resultative	7) self-assessment and self-reflection concerning the critical analysis of the information received; 8) the ability to predict the result through critical thinking due to the information received

Students of two Ukrainian leading universities have participated in the pedagogical experiment. We have selected Luhansk Taras Shevchenko National University and Volodymyr Dahl East Ukrainian National University as two universities which relocated during the years of the information-hybrid war in Ukraine.

After the experiment we came to the conclusion that motivational skills appeared to be the most developed in students. Their average rate in Control group (CG) is 33% and in Experimental group (EG) is 32%. Cognitive skills are less developed, their average rate in CG is 22% and in EG - 27%. We must admit that the data for this criterion in the experimental group is higher than in the control group. It indicates that the experimental group has a higher success rate than the control group. However, the success rate is not vital to critical thinking development, so it will not have a significant impact on the general indicator of critical thinking in the process of its development.

The indicator of students' activity skills is at the lowest level of development, as its average rate in CG is 10% and in EG - 16%. Resultative-reflexive skills are also underdeveloped in students, sufficient level of development is observed only in about a quarter of students and the average rate in CG is 27% and in EG - 26%.

Comparing the average indicators of control and experimental groups, we can see that the level of students' critical thinking development is approximately equal in all criteria and indicators.

The analysis of the results has led us to the conclusion that the level of critical thinking in students in the context of information security is insufficient. It should be taken into account when developing appropriate pedagogical conditions and modern methods for students' critical thinking development. The insufficiency of the level of students' critical thinking development in the context of information security is supported by several arguments. Students' professional training is mostly focused on knowledge acquisition, while their skills remain underdeveloped. Obviously, students are expected to independently find the ways to put their knowledge into practice through critical thinking, but teacher-trainers do not control how it really happens in practice.

During the formative stage of the experiment in the course of achieving the goal set, we proposed to develop a curriculum for the course "The specifics of students' critical thinking in the context of information security"; to develop an optional distance course on optimization of students' critical thinking on the background of information and communication technologies.

After the implementation of the suggested course, we have obtained the following results presented in Table 3.

Table 3. Distribution of students from control group according to their level of critical thinking development according to each criterion after formative stage

Criteria	**Levels** the number of people in %					
	Low		Average		High	
Experiment stage	Be-fore	Aft-er	Be-fore	Aft-er	Be-fore	Aft-er
1.Motivational	**26**	**19**	**41**	**44**	**33**	**37**
2. Content-related	**32**	**26**	**46**	**39**	**22**	**35**
3. Activity-based	**34**	**23**	**56**	**39**	**10**	**38**
4. Resultative	**29**	**19**	**44**	**30**	**27**	**51**

According to the results of final diagnostics of indicators and levels of critical thinking development in students from control and experimental groups, we have obtained the data, which proved the efficiency of the implementation of the special course "The specifics of students' critical thinking in the context of information security", as well as an optional distance course on optimization of students' critical thinking on the background of information and communication technologies. We have obtained the following results presented in Table 4.

General tendency of variability of indicators and levels of students' critical thinking is almost identical in dynamics. At the ascertaining stage of the experiment, the majority of students from CG (44%) showed an average level and thus all indicators in CG needed improvement. The data from two tables proves that in both groups there is a tendency for the predominant development of indicators of students' critical thinking in the context of information security. However, comparing the results obtained from control and experimental groups, we have noticed a certain difference. Thus, the experimental group's indicators are higher than those of the control group.

Table 4. Distribution of students from experimental group according to their level of critical thinking development according to each criterion after formative stage

Criteria	**Levels** the number of people in %					
	Low		Average		High	
Experiment stage	Be-fore	Aft-er	Be-fore	Aft-er	Be-fore	Aft-er
1.Motivational	**25**	**11**	**43**	**33**	**32**	**56**
2. Content-related	**25**	**12**	**48**	**31**	**27**	**57**
3. Activity-based	**34**	**15**	**50**	**28**	**16**	**57**
4. Resultative	**29**	**6**	**46**	**29**	**26**	**65**

To compare the results of summative and formative assessment stages, we also used the λ-Kolmogorov-Smirnov criterion [15]. The criterion allows to compare two empirical distributions and conclude whether they are consistent with each other. Here is a brief summary of the calculations applying this criterion.

The λ Kolmogorov-Smirnov criterion [15] is intended to compare two distributions: 1) empirical with theoretical, for example, uniform or normal; 2) one empirical distribution with another empirical distribution.

The criterion allows to find the point in which the sum of accumulated divergencies between two distributions is the largest and to assess the validity of this divergency.

If, in the χ^2 method, the frequencies of two distributions are compared separately according to each category, then under the λ Kolmogorov-Smirnov criterion firstly the frequencies from the first category are compared, then the sums of the first and the second categories are compared, then the sums of the first, the second, and the third categories are compared, and so on. Thus, each time we match the frequencies accumulated in this category.

If the divergencies between the two distributions are significant, then at some point the difference in accumulated frequencies will become critical, and we shall be able to recognize the divergencies as statistically valid. Hypotheses to be verified are the following: H0: the divergencies between two distributions are unreliable; H1: the divergencies between two distributions are reliable.

Let's describe the algorithm for calculating the λ criterion by comparing two empirical distributions [15].

1. Insert into the table the names of the categories of the criterion (the first column) and the corresponding empirical frequencies obtained in distribution 1 (the second column) and in distribution 2 (the third column).

2. Calculate empirical frequencies for each category for distribution 1 by the formula:

$f^*e=fe/n1$,

where fe is the empirical frequency in this category;

n1 is the number of examinations in the sample. Insert the empirical frequencies for distribution 1 into the fourth column.

3. Calculate the empirical frequencies for each category for distribution 2 by the formula:

*f*e=fe/n2,*

where *fe* is the empirical frequency in this category;

n2 is the number of examinations in the 2nd sample.

Insert the empirical frequencies for distribution 2 into the fifth column of the table.

4. Calculate the accumulated empirical frequencies for distribution 1 by the formula:

$$\sum f^*_i = \sum f^*_{i-1} + f^*_i$$

where Σf^*_{i-1} is the frequency accumulated in the previous categories;

i is the number of the category;

f^*_i is the frequency in this category.

Insert the results obtained into the sixth column.

5. Calculate the accumulated empirical frequencies for distribution 2 by the same formula and insert the result into the seventh column.

6. Calculate the difference between the accumulated frequencies for each category. Insert the absolute values of the difference, excluding their sign, into the eighth column. Mark them as *d*.

7. Denote in the eighth column the largest absolute value of the difference d_{max}

8. Calculate the value of the criterion by the formula:

$$\lambda = d_{max}\sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}}$$

where n_1 is the number of examinations in the first sample;

n_2 is the number of examinations in the second sample.

9. According to the tables in Appendix G, determine the level of statistical significance which the acquired λ value corresponds to.

If $\lambda_{emp} \geq 1.36$, then the divergencies between the distributions are reliable at the level of $p < 0.05$. If $\lambda_{emp} \geq 1.63$, then the divergencies between the distributions are reliable at the level of $p < 0.01$. Basic data for calculations are given in the table (see Appendix G), the results of the calculations by the described above algorithm are given in Table 5.

The analysis of Table 5 shows that the empirical value of the λ_{emp} criterion at summative assessment stage is less than the critical value of 1.36 for all the criteria (corresponding values are 0.130, 0.955, 0.829, and 0.278), therefore, the differences between the distributions in control and experimental groups at summative assessment stage are statistically insignificant ($p > 0.05$).

Table 5. Comparison of the distributions in CG and EG of students from control group according to their level of critical thinking development according to each criterion after formative stage by the λ Kolmogorov-Smirnov criterion.

Criteria	The empirical value of the λ Kolmogorov-Smirnov criterion when comparing the control and experimental groups at summative assessment stage	The empirical value of the λ Kolmogorov-Smirnov criterion when comparing the control and experimental groups at formative assessment stage
Motivational	0.130	2.605
Content-related	0.955	2.990
Activity-based	0.829	26. 01
Resultative	0.278	1.906

As we can observe, the empirical value of the λ_{emp} criterion for all the criteria at formative assessment stage exceeds the critical value of 1.63 (corresponding values are 2.605; 2.990; 2.601; and 1.906); consequently, the differences between the distributions in control and experimental groups after the experiment are defined at the level of $p < 0.01$

Consequently, the results of the processing of experimental data by mathematical statistics method (the λ Kolmogorov-Smirnov criterion) prove the efficiency of the created pedagogical conditions for the students' critical thinking development in the context of information security.

5 Conclusions

Experimental and research work on students' critical thinking development in the context of information security, as well as analysis of the results obtained through the developed system of criteria, showed rather steady and positive dynamics of particular indicators and general level of critical thinking of students involved into experimental work. Consequently, the successful solution of the problem of students' critical thinking development at theoretical and practical levels has proved the general hypothesis of the study that the process of students' critical thinking development in the context of information security should be carried out via the introduction of the special course "The specifics of students' critical thinking in the context of information security", as well as an optional distance course on optimization of students' critical thinking on the background of information and communication technologies.

The given study does not cover all the aspects of the problem under discussion. Issues related to the development of critical thinking in the context of distance learning, searching the effective methods to correct the consequences of insufficient development of critical thinking in students require further study.

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