TECHNOLOGY, CREATIVITY, IMPLEMENTATION

EFFECTIVENESS AND SAFETY OF STUDENTS' WORK WITH DIGITAL LEARNING ECOSYSTEMS

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Summary

The application of digital ecosystems to various activity types is an objective reality. One of the areas of activity that is currently undergoing a stage of active digitalisation is the educational system. As a result, a separate segment of digital ecosystems appeared − the digital learning ecosystem. The essential issues in the operation of digital learning ecosystems are the learner's efficiency and safety when interacting with them. This issue has become relevant due to the recent transition to a remote learning mode because control of the effectiveness and safety of interaction with the digital learning ecosystem has decreased. Thus, the paper puts forward a hypothesis: the efficiency and safeness of a student's work with a digital learning ecosystem in a remote work depend on three components: the level of digital competence; ergonomics of the digital learning ecosystem; ergonomic organisation of the workplace. An experiment was carried out to research the hypothesis. The students in the first year of studying the bachelor's qualification level from the Simon Kuznets Kharkiv National University of Economics took part. The Personal Learning Systems was chosen as the studied object. The hypothesis got confirmation during the study. In addition, a heuristic model of student interaction with a digital learning ecosystem was proposed based on the results. According to the model, teaching students such interdisciplinary sciences as cognitive and organisational ergonomics and building an individual learning trajectory will increase the effectiveness of students' interaction with digital learning ecosystems.

Keywords: digital ecosystem, digital competence, ergonomics, remote work, efficiency, performance.

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1. Introduction

Today's reality is the integration of digital ecosystems into various types of human activity. At the same time, the use of digital ecosystems has led to the formation of a new challenge for society, which consists in ensuring the implementation of two essential components in the

context of digitalization − human effectiveness and safety *(Bordi L., et al, 2018; Baptista J., et al, 2020; Oeij P.R.A., et al, 2019; Protasenko O., et al, 2021)*. This task is difficult since digital ecosystems have fundamentally changed man-machine interaction, which does not allow using standard approaches of ergonomics, labour protection, engineering psychology, labour physiology and other scientific areas to solve it. In addition, the solution of the problem complicates its versatility, which requires an interdisciplinary approach. In this regard, it is necessary to highlight the problems that make it up. Among them:

1. Changing the operating mode (transition of working activity from ordinary mode to online; use of mixed operating modes).
2. Blurring of the boundaries between working time and personal one.
3. Changing the methods, modes and volumes of communication between employees and employers and between employees.
4. Multitasking work.
5. The level of digital competence of the employee and the efficiency of the digital ecosystem.
6. Ergonomics of digital ecosystems.
7. Ensuring employee safety in the conditions of remote work.

Some of the presented problems were considered and studied in-depth, and methods for their solution were proposed *(Hasle P., et al, 2013; Stich J. F., et al, 2015; Protasenko O.F., et al, 2020)*. However, in our opinion, the issues of the employee's digital competence; the effectiveness of his activities, the ergonomics of working programs interface; employee safety in the remote work conditions have not been studied enough.

2. Problems of efficient and safe operation of digital ecosystems

Digital competence is the person's ability to confidently, effectively, critically and safely choose and apply information and communication technologies in various areas of life and readiness for such activities *(Soldatova G. U., et al, 2015)*. Evidently, digital competence significantly affects the efficiency of the digital ecosystem, and in conditions of remote work, it receives priority to ensure its functioning. Therefore, the higher the digital competence level, the higher the ecosystem productivity. However, there is a contradiction: on the one hand, there is a request to perform work remotely using certain types of Internet applications (for example, zoom, e-mails, google docs, etc.); on the other hand, insufficient level of of the employee's digital competence for their efficient use. The problem of inadequate the digital competence level is due to:

1. A formal assessment of the employee's skills when hiring since the employer by default believes that if the applicant has the appropriate education, he has the required level of digital competence. However, this is not always the case because digital ecosystems are volatile. Thus, if an employee had a break from work (often even a minor one) or found himself in conditions of isolation from the team (as during a lockdown due to the coronavirus pandemic), then the employee's digital competence be significantly reduced, which leads to a decrease in performance on a whole.
2. The lack of systemic tools for employee preparation before starting the work; and updating their digital skills in the activity. The employee's digital skills need to be constantly updated. Moreover, sometimes this process occurs insensibly during the work operations, and sometimes it requires significant efforts from employees. At the same time, the employer often

uncontrollably transfers the issues of updating digital skills to the employee, who does not always have the opportunity to do it on his own, which also leads to a decrease in performance.

To the problem of the low level of employees' digital competence, one should add the question of the correctness of employees' self-assessment of their digital competence level. Employees often tend to overestimate their knowledge and skills since, in most cases, they do not use any objective assessment methods, which subsequently causes delays in the implementation of tasks, incorrect of their realisation, in more complex cases, emergencies. The listed problems contribute to a decrease in the efficiency of the digital ecosystem's functioning. Thus, the employee's digital competence directly affects the level of his safety and efficiency.

The digital ecosystem ergonomics. Despite the demand and high level of software development that supports the possibility of remote work, the employee and the employer do not always get the desired result. The information search on this issue showed that this situation is often caused by insufficient ergonomics organisation of digital ecosystems, which can lead to a slowdown in the speed of operations, incorrect actions and other consequences that reduce the quality and reliability of the employee's work.*(Bordi L., et al, 2018; Baptista J., et al, 2020; Oeij P.R.A., et al, 2019; Protasenko O., et al, 2021)*. As a result, there is a decrease in the efficiency of the digital ecosystem as a whole. Therefore, it is necessary to find ways to improve the ergonomics of digital ecosystems. For this purpose, it is needed to use tools that allow harmonising man-machine interaction in the digital ecosystem *(Briscoe, G., et al, 2011; Protasenko O. F, et al, 2021)*.

Safety of activities in remote work. Today's understanding of human safety is multicomponent. These components are different in nature of origin and impact on a person. However, they are closely related to each other. For example, anthropometric and psychological comfort of the workplace, sanitary and hygienic conditions meeting regulatory requirements, social well-being, the technical systems perfection, and others. However, we got to used considering them in the context of the traditional organization of the workplace, i.e. when there is an office space in which employees operate. In this case, the set of actions and their sequence to ensure the worker's safety is clear. However, today new activity types and working conditions have arisen. Thus, we need to update the existing rules on workplace safety. An example of a new activity type and working conditions is freelancing, in which employee location, working hours and conditions and other characteristics of the activity are unregulated. Another example is the lockdowns due to the COVID-19 pandemic, which caused a mass transfer of workers to remote work. In this case, no one controlled the quality of working conditions, which provoked problems with workers' mental and physical health due to the impossibility of separate working time from a personal, sedentary lifestyle, isolation from society, etc. Therefore, it is necessary to find ways to ensure the employee's safety in remote work.

3. Digital learning ecosystems

The analysis of the listed problems is interesting in the context of digital learning ecosystems, which are conditioned by many reasons. *(Cuerdo-Vilches, T., et al, 2021; Blundell, C., et al, 2016; Lin, M.-H., et al, 2017, Myhal, H.V., et al, 2019)*:

1. The scale of digital learning ecosystems application. They are used in institutions of multidirectional activity: from schools to large manufacturing companies.

2. Age coverage of participants in digital learning ecosystems – from schoolchildren to the elderly.

3. Polyvariance of the proposed digital learning ecosystems. Today, there are many forms of implementing the learning process through digital ecosystems: from an auxiliary tool that allows a person to develop skills, to disciplines that form a person's knowledge and skills;

4. The trend toward the use of blended and completely remote forms of education, which gets widespread since the onset of the pandemic;

5. Inadequacy in the digital competence assessment, which connected with the subjectivity of a person's ideas about this concept due to the widespread use of digital devices both for work and everyday life.

Research hypothesis: the effectiveness and safety of a student's work with a digital learning ecosystem in a remote work depend on the following components:

1. The level of student's digital competence.
2. Digital learning ecosystem ergonomics.
3. The workplace ergonomic.

4. Materials and Methods

The students of the Simon Kuznets Kharkiv National University of Economics in the first year of study were testees. They were in blended learning. The time of work in the classroom and remotely was approximately equal. The total number of testees was 74 people. We used the MOODLE system as the digital learning ecosystem, based on which "Personal Learning Systems" have been created and operated at the university.

We estimated three indicators:

1. The index of student's digital competence.
2. The workplace ergonomics in remote work.
3. The student's working effectiveness and involvement in digital work.

We estimated the index of student's digital competence using the methodology by the authors: G.U. Soldatova, T.A. Nestik, E.I. Rasskazova, E.Yu. Zotov. According to the test, the estimation of digital competence has four ranges: high, above average, average and low levels. We transformed and placed the test on the free online service Online Test Pad for the convenience of assessing the index of student's digital competence.

We estimated the workplace ergonomics using the test "Subjective assessment of the workplace ergonomics". We placed the test on a free Internet service Online Test Pad for the convenience of work. The test included several questions about the student's workplace ergonomics outside the university. According to the test, the subjective assessment included three gradations: high, medium and low levels of workplace ergonomics.

We used the quiz "Activity effectiveness and the degree of involvement in digital work" to estimate the student's working effectiveness and involvement in digital work. It included the estimation of the average grade for the previous semester and the assessment of student's involvement in working with digital ecosystems. We placed it on a free Internet service Online Test Pad for the convenience of working.

Students received access to the quizzes "The index of digital competence", "Subjective assessment of the workplace ergonomics", and "Activity effectiveness and the degree of involvement in digital work" via an Internet link. It was possible to pass the quizzes at any convenient time using any digital device with an Internet connection.

The results were summarized in the analytical database of the Internet service Online Test Pad. After that, we generated files for further data processing. We used statistical observations, correlation and comparative analyses to process the collected data. We visualized the obtained results using graphs and pie charts.

5. Discussion of results

In the first stage, we divided students into three groups under their performance indicators:

1. The first group − students with a high level of academic performance (average grade in the range of 90...100 points).

2. The second group − students with an average level of academic performance (average grade in the range of 74...89 points).

3. The third group − students with a satisfactory level of academic performance (average grade in the range of 60...73 points).

Further, based on the results of the students' quizzes, we performed a correlation analysis to establish relationships between:

1. Students' performance and digital competence.

2. Students' performance and the workplace ergonomics

3. Workplace ergonomics and well-being.

As a result of the correlation analysis, no statistically significant relationships were found. However, a comparative analysis of the change in the index of students' digital competence in groups showed the following regularity: that the higher the progress of students, the higher the index of their digital competence and the smaller the range of values in which it changes (Fig. 1).

An analysis of changes in students' performance and the results of evaluating workplace ergonomics in remote work in groups showed that there is no direct influence of workplace ergonomics on the efficiency of students' activities. However, we found the following regularity: the higher the students' performance, the higher the level of the workplace ergonomics and the smaller the range of values in which it changes. (Fig. 2).

Comparative and correlation analyses of changes in the workplace ergonomics and subjective assessment of students' well-being in groups showed the following result: workplace ergonomics positively correlates with the student's well-being (Fig. 3). Thus, workplace ergonomics in remote work affects student's safety in working with a digital learning system.

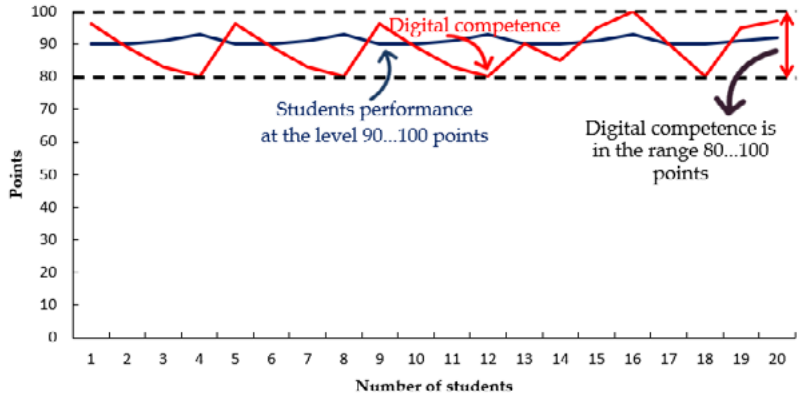
In the second stage, we divided students into three groups under the level of their digital competence: students with high, average and low levels of digital competence. We analysed two indicators based on the results of the quiz "Activity effectiveness and the degree of involvement in digital work". These are:

1. The student's involvement in working with the digital learning ecosystem;

2. The effectiveness of obtaining professional skills with the help of the digital learning ecosystem.

Based on the results of the analysis, we built diagrams (Fig. 4, 5).

Based on the presented diagrams, we concluded that there is the following regularity: the higher the level of student's digital competence, the higher the level of student's involvement in working with the digital ecosystem. Besides, students with a high level of digital competence have a high level of academic performance.



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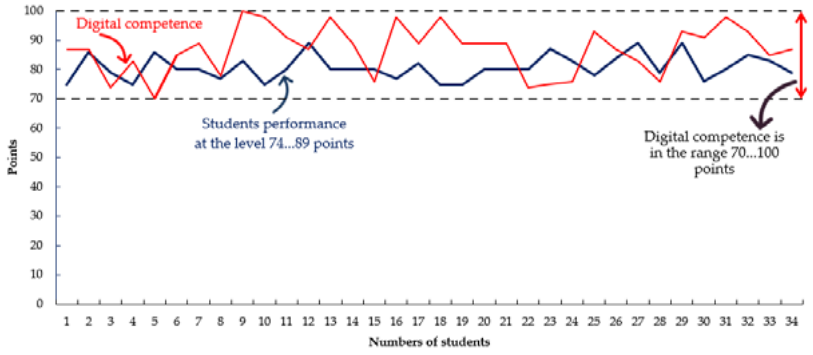

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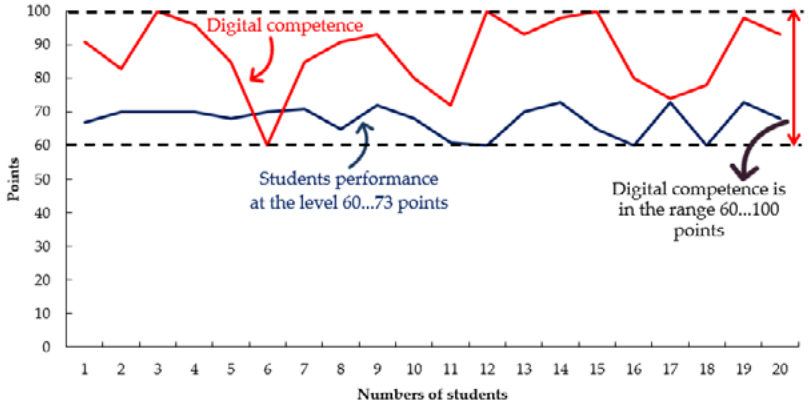

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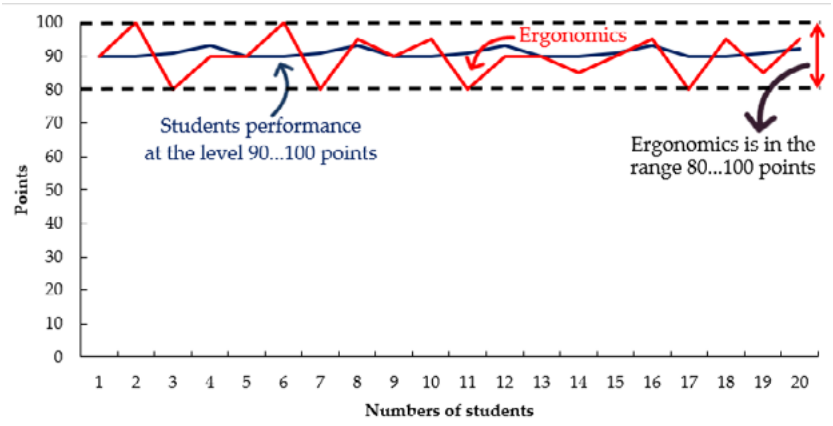
Fig. 1. Comparative analysis of changes in the index of students' digital competence in groups: (a) students group with a high level of academic performance; (b) students group with an average level of achievement; (c) students group with a satisfactory level of academic performance



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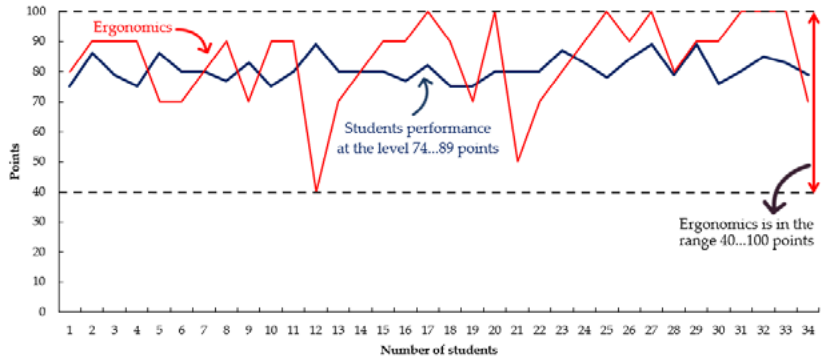

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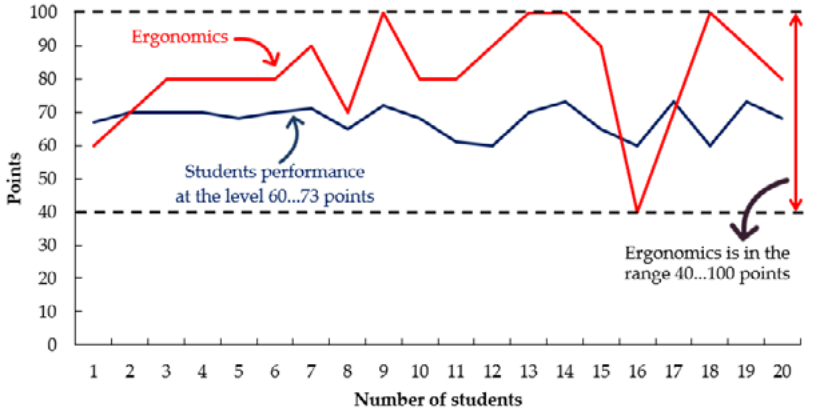

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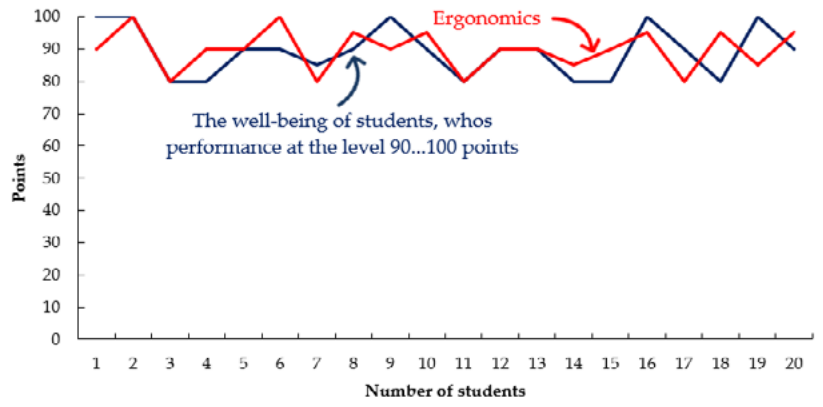
Fig. 2. Comparative analysis of changes in students' performance and workplace ergonomics in groups: (a) students group with a high level of performance; (b) students group with an average level of performance; (c) students group with a satisfactory level of performance



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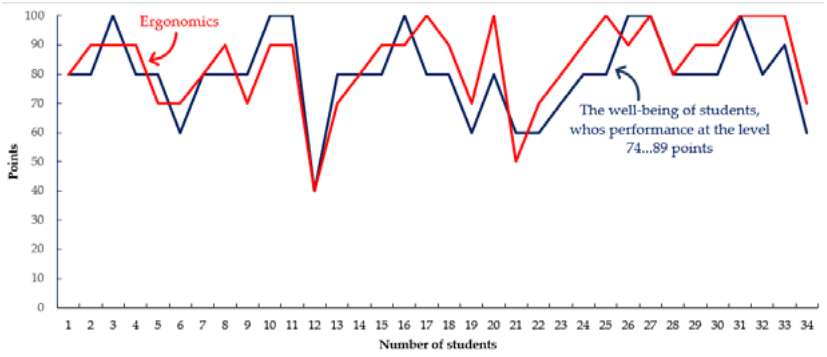

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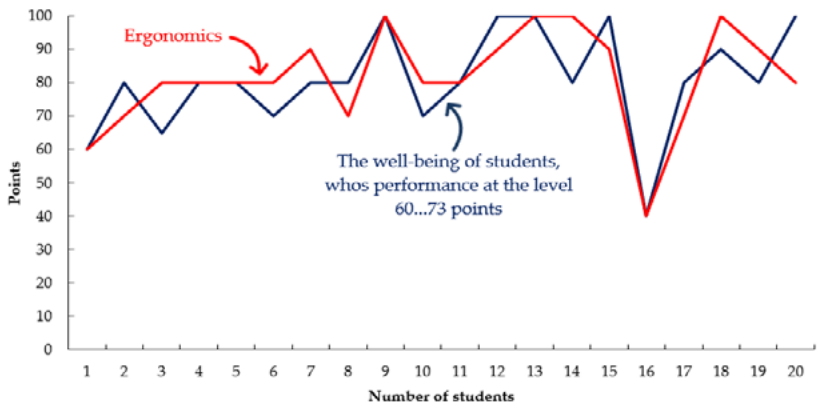

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Fig. 3. Comparative analysis of changes in students' well-being and workplace ergonomics in groups: (a) students group with a high level of performance; (b) students group with an average level of performance; (c) students group with a satisfactory level of academic performance

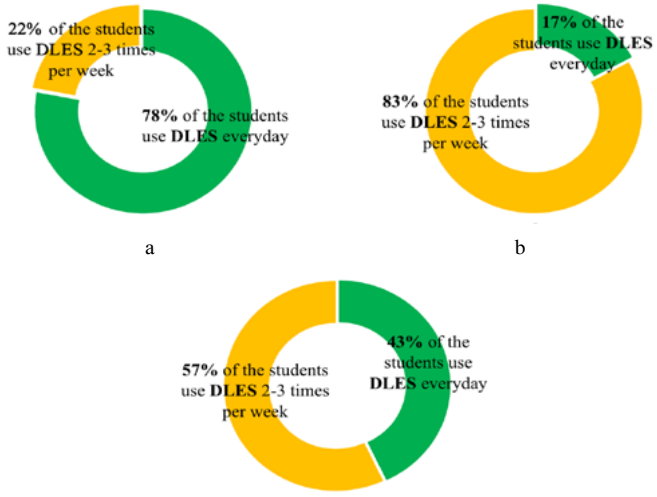

Fig. 4. Analysis of students' involvement in working with digital learning ecosystems (DLES): (a) students group with a high level of digital competence; (b) students group with an average level of digital competence; (c) students group with a low level of digital competence

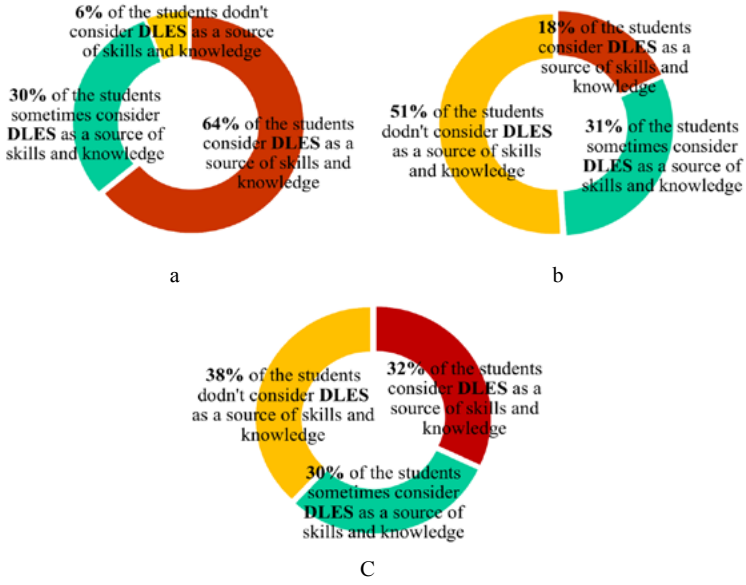

Fig. 5. Analysis of the subjective assessment of the use effectiveness of digital learning ecosystems (DLES) for obtaining professional skills and knowledge: (a) students group with a high level of digital competence; (b) students group with an average level of digital competence; (c) students group with a low level of digital competence

According to the diagrams, we concluded that students with a high level of digital competence use the digital learning ecosystem much more often as a tool for developing professional skills. Thus, we concluded that the skills development in working with digital ecosystems has a positive influence on the efficiency and safety of students' activities.

In the third stage, we estimated the students' subjective perception of the personal learning systems ergonomics. For the analysis, we used the results of the quiz "Activity effectiveness and the degree of involvement in digital work". We found that 92% of students rated the personal learning systems ergonomics of the interface as "excellent" and 8% − "good". In addition, 83% of students in the quiz indicated that the interface ergonomics of any digital learning ecosystem significantly affect the learning effectiveness.

According to the presented results, we obtained the following conclusions:

1. The level of students' digital competence affects the level of their performances. It manifested in the following regularity: the higher the student's digital competence level, the higher his performance under remote work (see Fig. 1). Therefore, increasing the students' digital competence level will increase their activities efficiency under remote work.

2. The level of workplace ergonomics indirectly affects the level of student performance. However, we determined the following regularity: the higher the workplace ergonomics under remote work, the higher student performance under the work with the digital learning ecosystem (see Fig. 2). Therefore, if students are introduced to the basics of workplace ergonomics under remote work, it will increase their activities efficiency.

3. The subjective assessment of the student's well-being depends on the workplace ergonomics under remote work (see Fig. 3). Therefore, mastering the practical skills of ergonomic organisation of workplaces under remote work will improve their well-being and, as a result, increase their work efficiency.

4. The level of students' digital competence affects the degree of their involvement in working with digital learning ecosystems. It manifested in the following regularity: the higher the level of students' digital competence, the higher their involvement degree in working with digital learning ecosystems (see Fig. 4).

5. The level of students' digital competence affects the students' subjective perception of the digital learning ecosystems' applicability for professional skills and knowledge development. It manifested in the following regularity: the higher the level of students' digital competence, the more often students use digital learning ecosystems to acquire professional skills and knowledge (see Fig. 5).

Thus, the hypothesis of the study, expressed at the beginning of the article, received confirmation, i.e. the effectiveness and safety of a student's learning with the help of a digital learning ecosystem in remote work depends on the level of his digital competence, the ergonomics of the digital learning ecosystem and the workplace ergonomic.

However, only 27% of students under remote work have high performance. Therefore, the question arises: how can we improve the students' efficiency? We researched on the relationship between the components of the digital learning ecosystem and the ways that student learns to work with it.

Based on a literature search (Stern, H., et al, 2019; Sun, S., et al. 2020; Mygal, G. V., et al, 2021), we identified three components: student's digital mindset, ecosystem's digital tools, and ecosystem's digital devices.

The digital mindset is the person's readiness to master and apply new technologies to solve the necessary tasks and the absence of internal psychological barriers under work in a digital environment. The student's digital mindset development level affects the degree of involvement

in working with digital learning ecosystems. The higher the level of digital mindset development, the higher the involvement level. At the same time, a digital mindset should be developed by using modern approaches to learning *(Myhal, H.V., et al., 2019; Mygal, G. V., et al, 2021)*.

The ecosystem's digital tools are programs, websites or online resources that a student uses to solve necessary problems. The ecosystem's digital tools ergonomics ensure the efficiency of students' information processing. As the study showed, the ergonomics of the MOODLE system's digital tools significantly influenced the involvement and efficiency of students' use of the digital learning ecosystem.

An ecosystem's digital device is an electronic device that can create, send, share, combine, receive, store, display or process information.

The presented components cannot exist in isolation from each other. We needed to connect the elements to ensure the effective and safe interaction of the student and a digital learning ecosystem. For this purpose, we used the principles of cognitive, organisational and software ergonomics. It allowed us to propose a heuristic model for effective and safe interaction between a student and the digital learning ecosystem (Fig. 6).

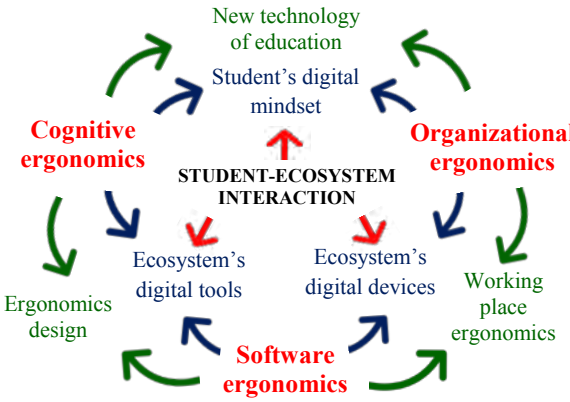

Fig. 6. Heuristic model of student interaction with digital learning ecosystem

According to the presented model, to ensure effective and safe interaction of a student with a digital learning ecosystem, such a component as new educational technologies is needed, the key element of which is the development of an individual student's learning path. Also, increasing the effectiveness of training contributes to the acquaintance of students with cognitive and organisational ergonomics. It will allow considering the student's individuality, the motivational sphere characteristics, functional state, etc.

It should be noted, that the traditional conservative organization of education contributes to the divergent thinking formation among students. At the same time, against the background of in-depth immersion in the fields of knowledge necessary for students, not enough attention is paid to interdisciplinary connections and systemic problems. It limits the possibilities for the formation of students' creative potential. In particular, the further development of their cognitive abilities and intuition requires achieving a balance of creative (divergent) and critical (convergent) thinking, which contributes to the development of non-linear thinking. That is why the student's personal choice of information sources, processing means, display and analysis play an essential role in the knowledge formation process. This moment is also considered within the framework of the proposed model.

Thus, the presented model theoretically contributes to increasing the efficiency of interaction between the student and the learning ecosystem. Of course, the proposed model requires further testing, which we will implement at the next stage of the study.

6. Conclusions

To sum up, we have come to the following general conclusions:

1. Today, the issues of digital competence, interface ergonomics, and workplace ergonomics are essential to ensure the safety and efficiency of humans in a remote work environment.

2. Experimental studies of the effectiveness and safety of the students work with the digital learning ecosystem using the example of the Personal Learning Systems showed that:

− increasing the students' digital competence level contributes to increasing the efficiency of their performance and involvement in working with digital learning ecosystems;

− studying the basics of workplace ergonomics under remote work will allow students to increase their work efficiency and safety within the digital learning ecosystem;

− the interface ergonomics of the digital learning ecosystem is essential for efficient and safe work. The results of the students' survey showed that 83% of respondents believe that the interface ergonomics of the digital ecosystem directly affects the efficiency of activities.

3. We proposed a heuristic model of student interaction with the digital learning ecosystem based on the study. According to the model, teaching students such interdisciplinary sciences as cognitive and organisational ergonomics and building an individual learning trajectory will increase the effectiveness of students' interaction with digital learning ecosystems.

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