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Computer-oriented management of students' educational activity in informatics practicum

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Abstract. The paper explores various types of managing students' educational activity, focusing on the educational discipline "Practicum of problem solving in informatics" for third-year students aspiring to become informatics teachers. The study aims to realize pedagogical conditions for computer-oriented management of students' educational activity. The courseware design revolves around a progressive shift from direct management to self-management, with co-management and subsidiary management as intermediate stages. The information and communication educational environment is built on the Moodle learning management system, with the Workshop elements playing a central role in managing students' educational activity. The suggested approach has been evaluated through pedagogical observation and assessment, demonstrating its efficiency. Furthermore, the study highlights students' lack of competency in time planning and introspection based on experimental data.[1]

Keywords: managing educational activity, computer-oriented management, informatics practicum, self-management, co-management, learning management system, informatics education, independent work, training in programming

1. Introduction

1.1. Statement of the problem

The informatization of the educational process has led to the creation of an information and communication educational environment in higher education institutions. This has significantly influenced the goals, content, methods, and means of students' educational activities, as well as the forms of organization. The use of modern computer tools for management tasks in the educational process represents a transition to a new type of management – computer-oriented. This new approach not only serves the achievement of learning goals but also helps students become active participants in their own education. The use of information and communication technologies is associated with the development of innovative management practices and the

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integration of these technologies into the educational process. While there have been many theoretical and practical studies in this field, it remains a relevant and ongoing area of research.

1.2. Literature review

A comprehensive analysis of the theoretical and methodological aspects related to the management of independent learning activities of students in pedagogical higher education institutions was proposed by Malykhin [18]. Recently, suitable methodological systems have been incorporated into the educational process to facilitate computer-aided management of students' learning activities. The "Cloud Technologies in Education" workshop by Kiv et al. [7] examined information and communication educational technologies, particularly cloud technologies that are transforming education.

Lavrentieva et al. [17] explored new methods for organizing students' independent study activities in conjunction with the use of ICT and tools. Velychko and Shulga [26] proposed computer-based tools to support students' independent experimental activities in the study of quantum physics, providing assistance in instrument setup, measurements, and results processing.

Vlasenko et al. [27] are developing an educational site called "Differential Equations" to aid students' learning activities. The site offers a theoretical framework, practical classes, online and email consultations, testing, discussion cases, and a forum. It supports course teaching and assists students in solving practical research problems.

Podlasov, Matviichuk and Bryhinets [23] suggested elements of blended learning in physics at a technical university based on programmed learning (where students learn new material or consolidate their knowledge) using the Moodle system's Lesson element. Kyslova and Slovak [16] developed methods for using a mobile learning environment for future electromechanical engineers studying higher mathematics. These methods involve the complex use of computer tools: Google Workspace for Education (for texts, diagrams, links, videos), GeoGebra and CoCalc environments (for practical tasks and research with developed models), Drawings (for generalizing and systematizing concept connections), Forms (for testing), CoCalc (for task generation), Classroom (for tool integration), and Calendar (for scheduling training activities).

Triakina et al. [25] analyzed e-learning tools for self-education and proposed ways to implement these tools into professional training. Kravtsov [14] analyzed methods and technologies for monitoring the quality of electronic educational resources. Pinchuk et al. [22] emphasized the flexibility and adaptability of pedagogical systems as principles for a significant transformation of the education system, which requires comprehensive pedagogical diagnostics and prognosis in the educational process.

Bilousova, Kolgatin and Kolgatina [2] developed a methodical system for computer-oriented management of independent work of future teachers studying computational (numerical) methods. This system is based on specially designed computational models in the MathCAD environment and uses the Moodle learning management system to manage students' independent work.

It's worth noting that reorienting the educational process towards students' self-management of their cognitive activity not only enhances student autonomy but also personalizes education. By determining each student's individual trajectory of educational and cognitive activity based on their individual cognitive abilities, the necessary prerequisites for developing their skills for systematic and continuous professional self-improvement are created. Useful analyses in this direction were suggested by Kruk and Zhuravleva [15].

Santos, Verbert and Duval [24] proposed a tool designed to enable students to reflect on their activities. A unique analysis of the process and steps for transitioning students' independent work management from direct supervision to self-management was suggested by Bilousova, Kolgatina and Kolgatin [4]. This theoretical analysis was applied in the training of future informatics teachers, allowing the authors to observe the connections between students' introspection and their competence in self-management.

Self-regulated learning was discussed by Nussbaumer et al. [21]. They emphasized that cognitive and meta-cognitive activities are not directly measurable, so measurable actions should be mapped to cognitive and meta-cognitive learning activities [21]. However, the results observed in our review are not sufficient to construct a complete student model for pedagogical prognosis.

1.3. Objectives

The full potential of computer-oriented management of students' educational activities remains untapped, as revealed by the preceding analysis. This necessitates the exploration of pedagogical conditions that, when implemented, enhance the effectiveness of such management. Our aim is to discover methods that assist students in achieving superior educational outcomes and in adopting an active role in managing their independent work. We also require approaches for measuring the parameters of a student model for pedagogical prognosis and for effectively selecting the appropriate type of management. This task is intricate and highly complex, and cannot be resolved in a single study. Our work is aimed at addressing this issue by examining some basic aspects of the student model and correlating some of its parameters with the efficiency of certain types of management.

The *objective* of this paper is to conduct a theoretical and practical examination of introspection as a pedagogical condition for effective computer-oriented management of students' educational activities in information and communication educational environments.

2. Theoretical background

Various interpretations of the concept of management in pedagogical systems are presented in psycho-pedagogical literature. For instance, Markov [19] perceives management as the organization of purposeful actions, while Itelson [6] views management as actions aimed at achieving a pre-established goal. Korshunov [12] believes that management is the organization of a process that ensures the attainment of a predetermined goal. Filippov [5] defines management as the purposeful influence of the subject on the object, resulting in changes to the object. Nechaev [20] discusses management as purposeful regulation of processes. In some studies, management is seen as an element of a system that links all its components and aligns them with the goal. Thus, Yakunin [28] sees the essence of management in the interaction between the student and the teacher, which is conducted in line with set goals and aims to activate the student's activity in the learning process and achieve the required results. We concur with all these statements, which underscore certain characteristics of management and affirm its connection with activities. This is also defined by the new interpretative dictionary of the Ukrainian language: "To manage – 1. To direct activity, work of someone, something; be led by someone, something; manage. 2. To direct the course of a process, to influence the development, the state of something" [29]. Based on this analysis of pedagogical research on the issue, we define managing student's educational activity as realizing interaction between a student and a teacher, aimed at activating student's activity in the educational process and achieving educational goals. As a result of this interaction, the social and cognitive experience of the student changes, acquiring traits of independent, purposeful activity in order to become ready to solve future professional problems.

The advancement of information and communication technologies lays the groundwork for enhancing the efficiency of managing students' educational activity in contemporary higher education processes. Considering the evolving role of teachers as tutors or moderators who assist students in selecting and constructing individual educational trajectories, new qualities of management are seen in its variability and coordination with individual capabilities, needs, and requests of students. This form of management not only helps students acquire knowledge and skills according to curricula but also increases their involvement in managing their own educational activities. It facilitates a progressive transition from direct management to co-management, subsidiary management, and eventually self-management. ICT-oriented management of student's educational activity is a multi-stage process (information collection, objective setting, decision-making, decision implementation, result monitoring and evaluation, adjustments) that employs suitable ICT tools at each stage. Implementing student self-management using modern, robust computer management tools signifies a transition to a new type of management – computer-oriented – capable of providing higher quality management. This new quality cannot be theoretically proven but has been observed in educational processes. We have analyzed our previous empirical work [1, 8–10] and can highlight key features of computer-oriented management of student's educational activity:

- **Adaptability**, which is based on comprehensive data on the required level of knowledge and skills for independent work, as well as on the dynamics of their acquisition.
- **Flexibility**, which involves gradually engaging a student in enhancing the management of their own independent work. This is achieved through a transition from direct management to co-management, subsidiary management, and ultimately self-management, based on an analysis of the accumulated experience of using a specific type of self-management and data on its effectiveness.
- **Timeliness**, facilitated by the ability to monitor task execution processes and the availability of communication resources. This allows for timely and targeted assistance and advice to the student, based on the accumulation and analysis of data on the progress and effectiveness of their educational activity.
- **Transparency**, which entails openness regarding the requirements for the results of educational activities, evaluation criteria, and rating indicators of a student's educational achievements.
- **Objectivity** in making managerial decisions, which is based on objective testing data and tracking the effectiveness of the student's educational activity.

The pedagogical conditions for effectively implementing the aforementioned management in the educational process have been substantiated based on an analysis of new opportunities for managing a student's educational activity:

- Designing an information and communication educational environment that contains varied educational-informative, instructive-methodical, software-instrumental, as well as communication resources for organizing and supporting the student's educational activity.
- Utilizing a system that automates the collection, accumulation, and analytical processing of performance indicators of a student's educational activity.
- Ensuring that all participants in the educational process are prepared to implement computer-oriented management of the student's educational activity.

These pedagogical conditions were tested in a comparative pedagogical experiment conducted in one of the present paper authors' PhD thesis [11]. The results of this experiment have demonstrated that adherence to these suggested pedagogical conditions contributes to increasing the efficiency of computer-oriented management of independent work by future teachers during their natural and mathematical training.

Only a comprehensive application of all these conditions ensures effective management. The implementation stage of ICT-oriented student's educational activity management is crucial, as it is when the student actively participates in this management as an integral part of the educational process. Understanding the nature of interconnections between the teacher and the student (table 1) is vital for developing flexible management based on different types of management (direct management, co-management, subsidiary management, and self-management) [4].

Table 1 provides a comprehensive overview of how tasks are set, methods are chosen, resources are suggested, operation sequences are determined, task execution processes are corrected, help is provided, and results are summarized under each type of management. It highlights the gradual shift in responsibility from the teacher to the student as we move from direct management to self-management. This table serves as a valuable resource for understanding the dynamics of different management types in an educational setting.

It's important to note that only a comprehensive application of all conditions ensures effective management. The implementation stage of computer-oriented student's educational activity management is crucial, as it is when the student actively participates in this management as an integral part of the educational process. Understanding the nature of interconnections between the teacher and the student is vital for developing flexible management based on different types of management (direct management, co-management, subsidiary management, and self-management) [4].

3. Empirical research methodology

The aforementioned approach to managing students' educational activity was implemented in the context of programming training for students. The information and communication educational environment was established on the Moodle learning management system platform. This

Table 1
Activities of the subjects of the educational process at different management types on the stage of implementation of the decision.

Type of management			
Direct management	**Co-management**	**Subsidiary management**	**Self-management**
The teacher sets a task for the student	The teacher discusses a task with the student	The student chooses a task from a database	The student formulates a task and coordinates it with the teacher
The teacher sets the methods of the task execution	The teacher discusses the methods of the task execution with the student	The student chooses the methods of the task execution from suggested by the teacher	The student determines the methods of the task execution independently
The teacher suggests necessary resources to for the student	The teacher suggests necessary resources to for the student	The student chooses necessary resources from the given resource base	The student determines the necessary resources independently
The teacher gives the example of the correct operation sequence (detailed instruction)	The teacher gives the common schema of the operation sequence (framework instruction)	The student determines the operation sequence independently	The student determines the operation sequence independently
The teacher provides current correction of the task execution process	The teacher adjusts the process of completing the task, if necessary	The teacher adjusts the process of completing the task, if the student ask him for help	The student controls the task completing process independently
The teacher provides the student with current systematic help	The teacher helps the student, if necessary	The teacher helps, if the student asks	The teacher helps, if the student asks
The teacher gives the pattern of report to summarising obtained results. The student acts according the model	The teacher gives the plan of report to summarising obtained results. The student acts according the plan	The teacher gives the requirements to report and summarising obtained results. The student produces the analysis of obtained results independently	The student coordinates the form of report with the teacher and produces the analysis of obtained results independently

environment included built-in communication resources, as well as references to educational-informational resources and instructional-methodological materials related to programming basic algorithmic structures, to organize and support students' educational activities.

The initial stage of empirical work was carried out in a problem-solving practicum in informatics for future informatics teachers, involving 10 students. Each student's computer was equipped with software-instrumental resources, including the Eclipse environment and common information technology tools. The primary information channel was interactive lectures, where program elements were analyzed in detail. Students' educational activities during these interactive lectures were directly managed, as they took notes in the form of parallel development of the suggested and analyzed algorithms as Java programs. Some students participated in co-management of educational activity during interactive parts of these lectures, while others continued to execute tasks under direct management, using ready code fragments and following the teacher's time planning commands. The students' notes, in the form of developed and tested programs, served as instructional materials for managing students' independent activity in problem-solving.

Five Workshop activity elements were created in the Moodle course environment, and five series of individual tasks were proposed for each student on such topics as linear algorithms; branching; cycles; one-dimensional arrays; two-dimensional arrays. With 10 variants of tasks available, each student received an individual variant. An example of a full task series for one of these variants is shown in table 2. Each series contained three tasks of varying levels. Students were required to complete at least one task for passing or all tasks for a high grade. The first task assumed direct (but remote) management of students' educational activity, as this task was very similar to one analyzed at lecture. The second task assumed either direct or co-management. This task was based on some of the analyzed algorithms but was not entirely similar. Students could solve this problem using only the lecture notes (direct management). However, sometimes students needed additional information to solve the problem. They could ask the teacher or colleagues personally or use the built-in tools of Moodle (co-management), or use additional information resources (subsidiary management). The third task was challenging and assumed using algorithmic constructions that were not analyzed at lectures. Students had to discuss this problem with the teacher (co-management) or independently use additional information resources (subsidiary management). Thus, students independently and intuitively decided on using one of the above types of management for their own educational activity for each task based on their educational achievements and skills in independent activity.

Students submitted the results of their task execution to the Workshops. These submissions should include a correct program along with the author's tests to verify its correctness. The second phase of students' activity in Workshops involved reviewing and grading their peers' work – a phase known as the assessment phase. Only students who had completed the first stage of the task and submitted their work could participate in the assessment.

The assessment process, while creative, was directly managed. Students assessed according to a simple instruction: +1 point if the program is submitted and produces the required results; +1 point if the program works correctly with the author's tests; +1 point if the reviewer cannot suggest any tests that would reveal bugs. The grading of the assessment phase was automated, comparing each student's given grades with other reviewers' grades for corresponding works. The teacher also participated in the assessment as a reviewer, with a weight coefficient of 10.

This procedure represents our evaluation method. Thus, a student's grade for submission is the sum of the grades for three tasks, with each task graded from 0 to 3 as previously described. The student's grade for assessment was evaluated automatically using a built-in algorithm of the Moodle learning management system for the Workshop element.

Table 2: Example of tasks set for workshops.

Topic	The first task	The second task	The third task
Linear Algorithms	Develop a program for calculating the income of a family of 4 people for the specified income of each family member	Develop a program to calculate the rest when buying n units of goods at a price of x_1 dollars x_2 cents, if the box office submitted y_1 dollars y_2 cents	Develop a program to calculate the amount of money to buy n CD disks, if each individual CD disk costs x hryvnia, and a box of ten CD disks is sold at a discount of y percent
Branching	Develop a program to test knowledge in the history of science according the following scenario: 1) the computer submits the task: "Year of birth of Serhii Oleksiiovych Lebediev – an outstanding scientist, under whose leadership the first computer in the continental Europe was built"; 2) the user enters the answer as an integer number; 3) the computer compares the user's answer with the correct one (1902) and informs the user about the result of the check.	Develop the program which on the set air temperature recommends clothes: a) less than minus ten – "coat"; b) not less than minus ten but less than plus ten – "jacket"; c) not less than ten but less than eighteen – "sweater"; d) eighteen and above – "does not matter"	Develop a program that determines whether the brick will pass into a rectangular hole, according to the specified size of the hole (a, b) and the brick (x, y, z). Input may be not sorted in ascending order.
Cycles	In the treasury of the fairy kingdom are jugs of living water. All jugs are numbered sequentially. The amount of water in each jug is determined by the magic formula $\frac{i^2+1}{2i}$, where i is the number of the jug. Develop a program that for given numbers i_1 and i_2 finds the total amount of water in the jugs from i_1 to i_2 inclusive	For n numbers entered from the keyboard, compare the count of positive and negative numbers	For n numbers entered from the keyboard, find the length of the maximum series of numbers that are ordered in ascending order. Do not use the array

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Table 2 – *continued from previous page*

Topic	The first task	The second task	The third task
One-Dimensional Array Processing	Replace the surnames "Danko" with "Tanko" in given array of surnames	Delete items that are equal and next to each other from given array, which contains a list of company names	Two arrays of surnames are specified. Elements with the same index define the ancestor – descendant pair. Develop a program that identifies all the ancestors of a person by a given surname and writes their surnames to a new array in chronological order
Two-Dimensional Array Processing	Replace all negative elements of the 2D array with zeros	A square table is specified, each element of which determines the distance between cities. Assume that there are no errors in the table. Find pairs of cities with the minimal distance between them	A rectangular table is given: the number 1 indicates land, and the number 0 indicates water. Determine the number of islands. Assume that from one cell you can go to another "by land" if they are located next to each other vertically or horizontally.

During the course, the teacher conducted pedagogical observations. Students who did not submit their work on time completed each task at an additional time through personal discussions of the results with the teacher. These results were not included in this study.

At the end of the course, a final test was administered to future informatics teachers. This test, conducted in a classroom at a fixed time under teacher supervision, required students to design three programs of varying difficulty levels using algorithmic elements from different topics. Students who successfully designed a program at the satisfactory level could earn up to 74 grade points. If there were errors, the grade was reduced. Upon successful completion of the satisfactory level, students were given a task at the sufficient level (up to 89 grade points). Finally, a high-level task was suggested. Some students could not satisfactorily complete this test within the fixed time. They had additional attempts, but only the results of the first attempt were used in this study.

The second stage of our empirical work was carried out in the "Algorithms and data structures" course for future bachelors in Computer Science (Software and Applications Development and Analysis). We used the same series of tasks that were suggested to students via Workshop elements in the Moodle personal learning environment. The grading scheme was identical to that of the first stage: +1 point if the program is submitted and performs the required results; +1 point if the program works correctly with the author's tests; +1 point if the reviewer cannot suggest any tests that would reveal bugs. Students participated in grading alongside a teacher in an anonymous peer review process. This work supported the development of students' introspection skills and encouraged them towards self-management of their own independent work. The analysis of students' reviews used in this paper describes correlations between grading quality, submission quality, and student introspection competence.

The pedagogical environment differed significantly from that of the first stage due to different educational programs and the impact of the COVID-19 pandemic. Microsoft Visual Studio (C++) was used as software-instrumental resources. All students solved these problems outside of classroom settings due to COVID-19 restrictions [13]. There were only review lectures and one practical work session in classrooms. As such, students were not equipped with examples of solving similar problems but had some programming experience as a result of passing previous courses according to their curriculum. We can infer that management of students' independent work in problem-solving was either subsidiary or self-management. The personal learning environment in Moodle was a key component of courseware. The leading information channel was interactive lectures conducted via Moodle's Lesson element (direct management with answering short questions after each portion of information) as well as teacher consultations via Moodle's built-in messenger (co-management). The system of pedagogical diagnostics was based on analyzing workshop submissions and assessments, built-in lecture testing, and results from final programming tournaments. The material on base algorithms for linear data structure processing (linear algorithms, branching, cycles, one-dimensional arrays processing, two-dimensional arrays processing) covered only the first module of the course compared to future informatics teachers' curriculum.

Due to the COVID-19 pandemic, a final test for future computer science bachelors could not be administered. As a result, alternative measures were needed to compare students' educational achievements with the characteristics being investigated. We utilized the results of automated testing during students' engagement with the Lesson element in Moodle. The course included six such interactive lectures (not only for the investigated topics). The questions posed were both theoretical and practical. Students had the opportunity to attempt each lecture multiple times. We used the highest test results from each lecture as the test value. The average of these test values across the course was calculated to obtain an appropriate characteristic for each student. Additionally, we analyzed the average time that students spent studying and testing each lecture as an additional characteristic of their learning style.

Students had the option to pass the course without participating in the suggested workshops by independently studying corresponding material using the Internet and demonstrating their competences in tournaments. Eleven students, who are future bachelors of computer science, participated in these workshops.

4. Results and discussion

4.1. Introspection of future informatics teachers

The correlation between students' final test results and their average grades for submitted works was evaluated to estimate the validity of our assessment tools on the sample of future teachers of informatics (figure 1). The Pearson's correlation coefficient is 0.70, which is statistically significant at the 5% significance level.

The correlation between the quality of tasks executed by students and their skills in assessment

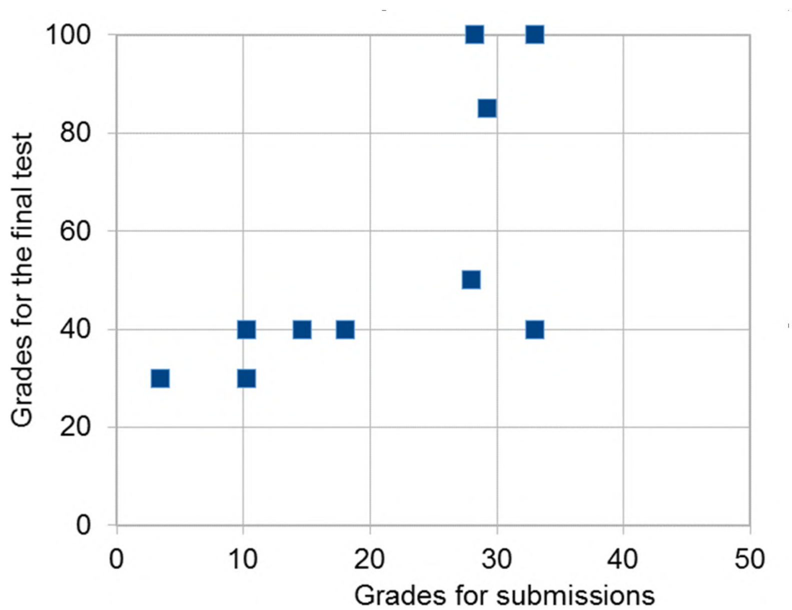

Figure 1: Correlation between students' final test results and students' average grades for submitted works (future informatics teachers).

appears to be very good for 7 students (figure 2). However, 3 students with the highest results of task execution did not participate in the assessment, so we cannot statistically prove this correlation due to the small sample size. According to our pedagogical observation, some students did not participate in the assessment due to their mistakes in time planning.

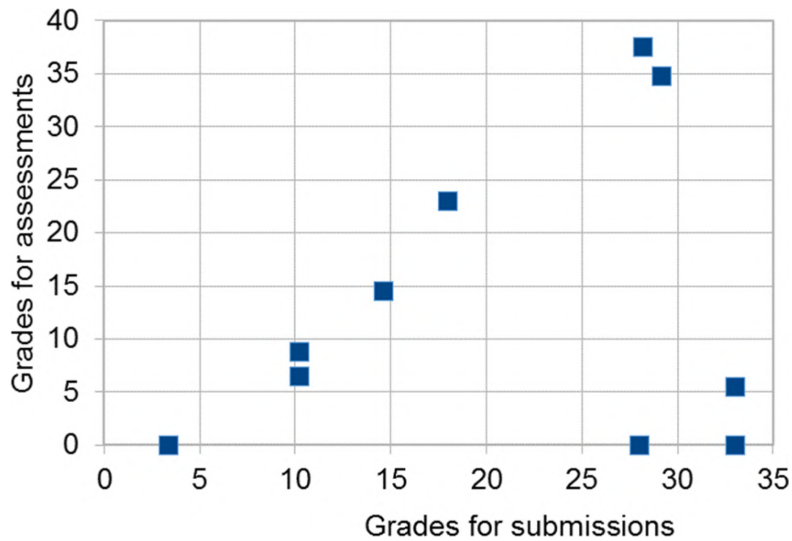

Figure 2: Correlation between students' average grades for assessment and average grades for submitted works (future informatics teachers).

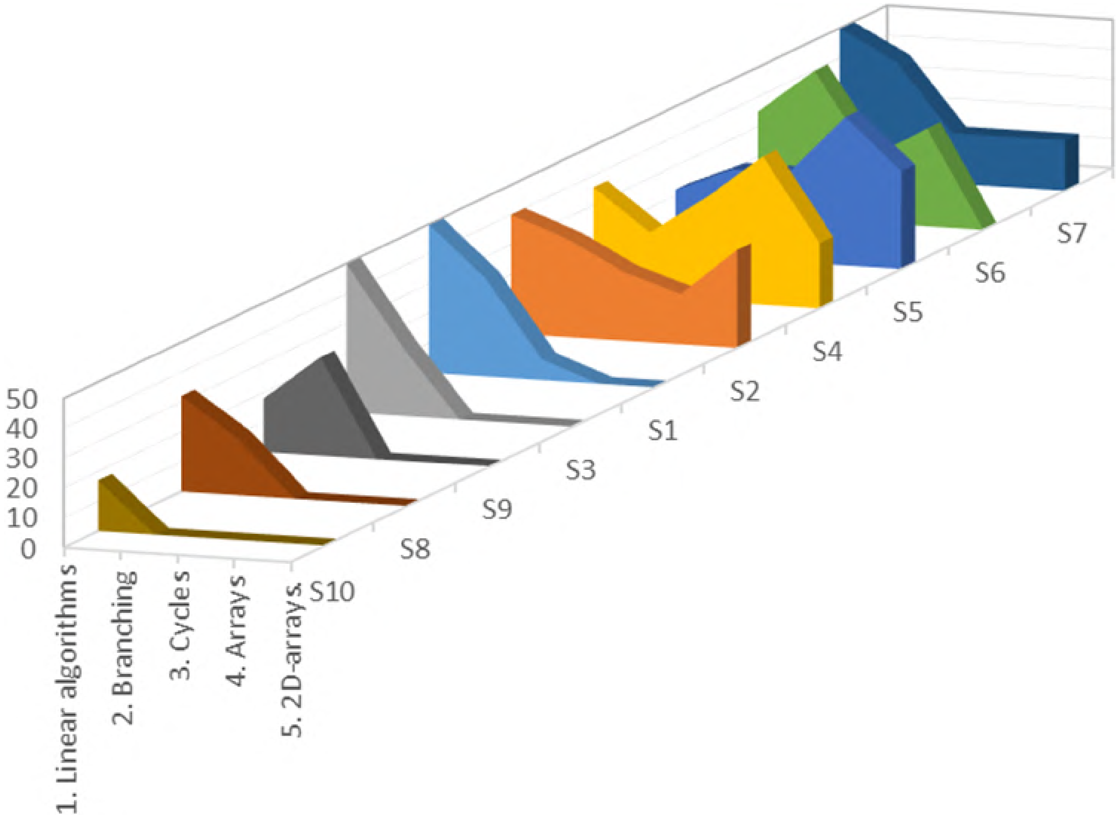

Figure 3: Students' progressing from the first topic task (Linear algorithms) to the last (2D-arrays). Students' names are shown as S1-S10. Vertical axis shows students' grades for submission. The maximum possible grade was 50 (future informatics teachers).

Not all students were able to maintain the proper pace of educational activity progressing from the first topic to the last (figure 3). Some of them worked effectively only in the beginning when direct instructions were comprehensive enough to execute some tasks. Due to low motivation and lack of basic skills in self-management, they did not transition to co-management on their own initiative. These students did not submit some works on time and then completed the tasks in classes with personal participation of the teacher in the process of programming and time planning. Therefore, we should develop a mechanism for preventive diagnostics of students' skills in self-management and timely transition them to direct management of educational activity. Also, we observe that direct management is an easier way of educational activity for some students. This way seems more comfortable for them. Thus, we should develop special methods to motivate this category of students for their progression to self-management of their own educational activity. However, other students actively used communication and additional sources to solve problems and did not decrease the level of submissions when progressing to the next, more difficult topic.

As expected, the most difficult task for the students was the third task in each Workshop, while the least difficult was the first task (figure 4). Analyzing the structure of student works

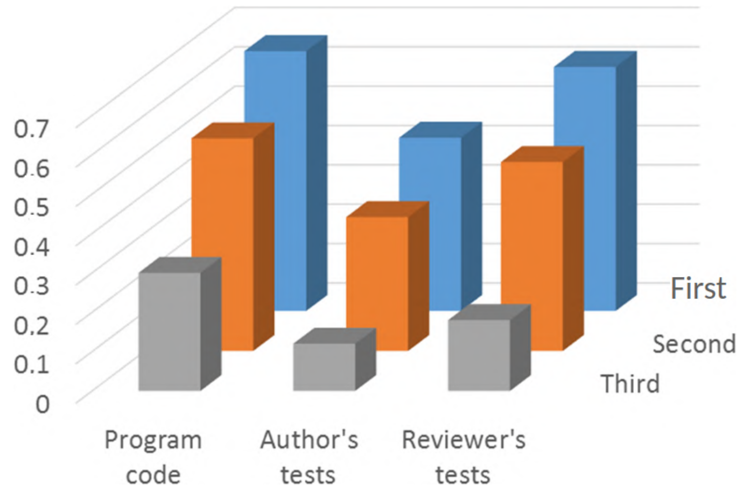

Figure 4: Part of submissions that satisfy to the criterion (program code, author's test, reviewer's test) on each task (first, second, third). This part was calculated as average for all 5 Workshops (future informatics teachers).

according to given criteria (figure 4), we can conclude that the most challenging aspect for students was not developing the program but ensuring that it works correctly. The author's tests were often absent or incorrect. The program, if present, was often correct, but sometimes reviewers' tests could find some bugs.

The analysis of the structure of students' work revealed that their competency in introspection was insufficient. In our view, introspection is a key component of self-management competency. Therefore, educational tasks should consistently include sub-tasks focused on introspection.

In summary, our experience in integrating various types of management of students' educational activity has led us to conclude that the provision of the aforementioned pedagogical conditions has enabled us to enhance the educational process in the "Practicum of problem solving in informatics". Flexible management of students' educational activity, with a timely transition from direct management to co-management and subsidiary management (and reverting when necessary), supported efficient learning. Despite students' involvement in practical work outside of the educational process, the goals of the "Practicum of problem solving in informatics" were successfully achieved.

4.2. Introspection of future computer science bachelors

As per the curriculum, future computer science bachelors received additional programming training, which resulted in higher performance (figure 5). Their introspection competence was adequate for testing their own programs, a skill that was more developed compared to future informatics teachers. However, there were instances when students failed to identify errors in these tests. Consequently, the grades for auto testing were lower than those for submissions: the program operates and processes some data with errors, these errors are highlighted by the author's test, but the author submits this test without recognizing the errors. Identifying errors that were not highlighted by the author's test proved to be more challenging. However,

Figure 5: Part of submissions that satisfy to the criterion (program code, author's test, reviewer's test) on each task (first, second, third). This part was calculated as average for all 5 Workshops (future computer science bachelors).

reviewers identified these errors, resulting in lower grades for reviewers' tests. This situation is a common occurrence in software development practice. Hence, introspection is identified as a crucial soft competency in this field of business.

We did not observe a trend of decreasing student activity and quality of submissions with an increase in task difficulty (figure 6).

In our view, this observation suggests that students in this sample did not require direct management of their independent work and attempted to solve complex problems. On the other hand, they might not have been as meticulous with "simple" problems.

Figure 7 displays the correlation between students' average grades for assessment and submissions. These grades were calculated as averages of corresponding grades for all 5 workshops. All grades are shown in relative values, so the range of values is from 0 to 1.

The above analysis indicates that introspection is a key integral characteristic of a student's learning style. It is an essential element of pedagogical conditions for high levels of student's independent work management up to self-management. Moreover, introspection is part of professional competences of software engineers. We observe a positive correlation between the signs of introspection and the signs of problem-solving in software development. Despite the satisfactory level of introspection observed in our study, we emphasize that any courseware needs special tasks for developing and monitoring students' introspection.

We conclude that the level of students' independent work management was sufficiently high as a result of providing theoretically grounded pedagogical conditions in teaching the course "Algorithms and data structures". The implementation of distant learning components

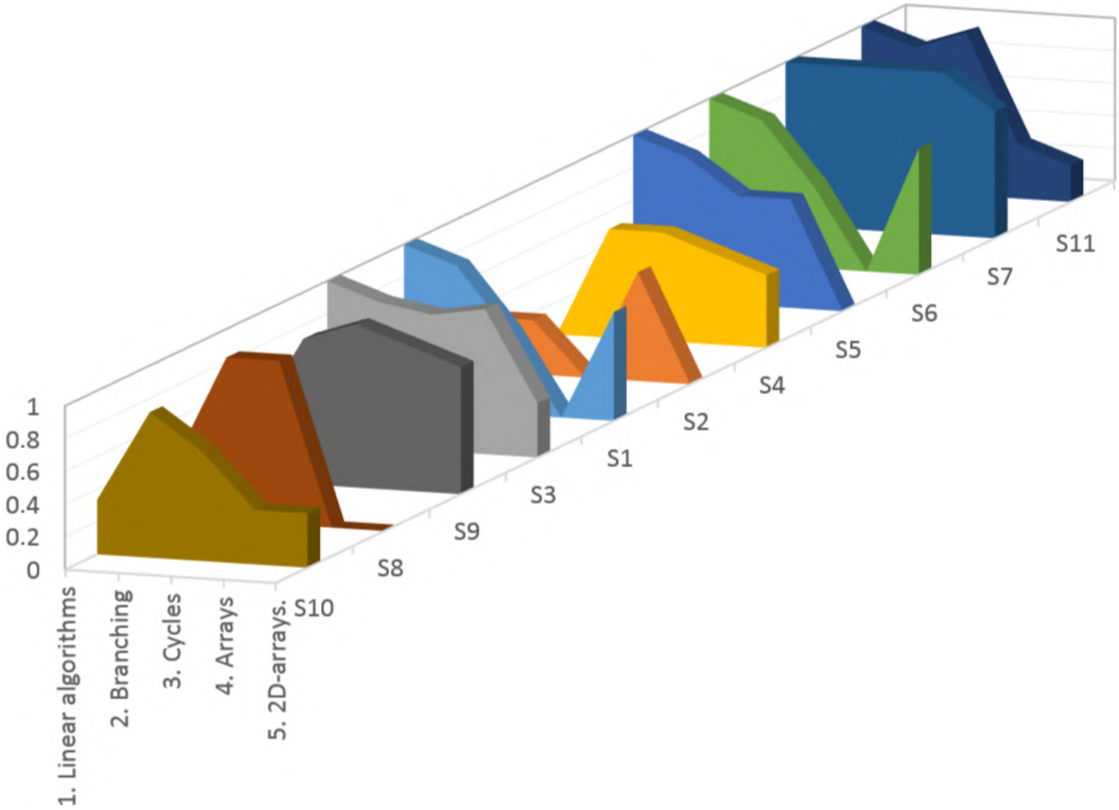

Figure 6: Progression of students from the first topic task (Linear algorithms) to the last (2D-arrays). Students' names are shown as S1-S11. Vertical axis shows students' grades for submissions. The maximum possible grade was 1.0 (future computer science bachelors).

in our courseware allowed us to monitor and timely adjust the levels of learning activity management for each student and supported students' self-management when COVID-19 pandemic influenced the educational process.

4.3. Correlation between introspection and success in directly managed learning

Direct management of students' educational activity, specifically their independent work, was organized while studying new material with the Lesson elements of the Moodle learning management system. Six such lectures were proposed: "Graph processing algorithms (data representation)"; "Graph processing algorithms (data analysis)";"Optimization problems on graphs"; "Basics of tree data structure"; "Application of tree data structure"; "Fundamental algorithms and their construction". These lectures required students to read educational material in short segments and answer corresponding questions online. The lecture work was graded based on the correctness of the student's answers. Students had unlimited attempts to listen to the lecture material and answer the questions. The highest grade for answering was used in the course grading system. The time taken for each attempt was recorded. This allowed

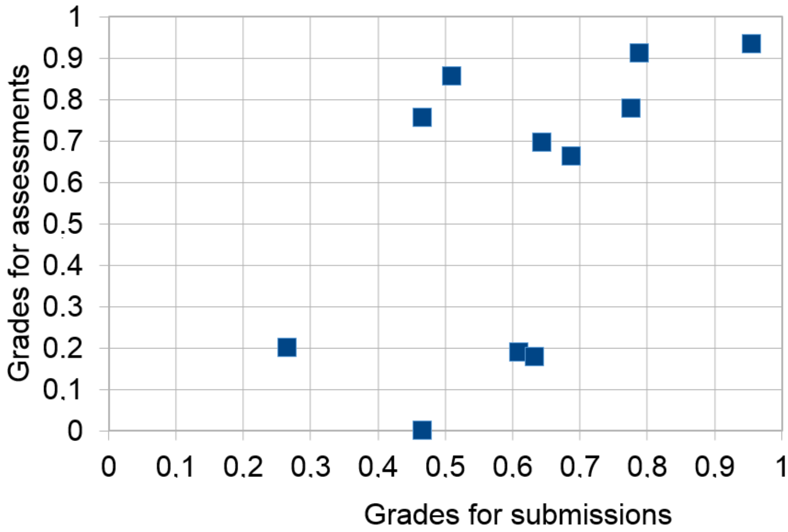

Figure 7: Correlation between students' average grades for assessment and average grades for submitted works (future computer science bachelors).

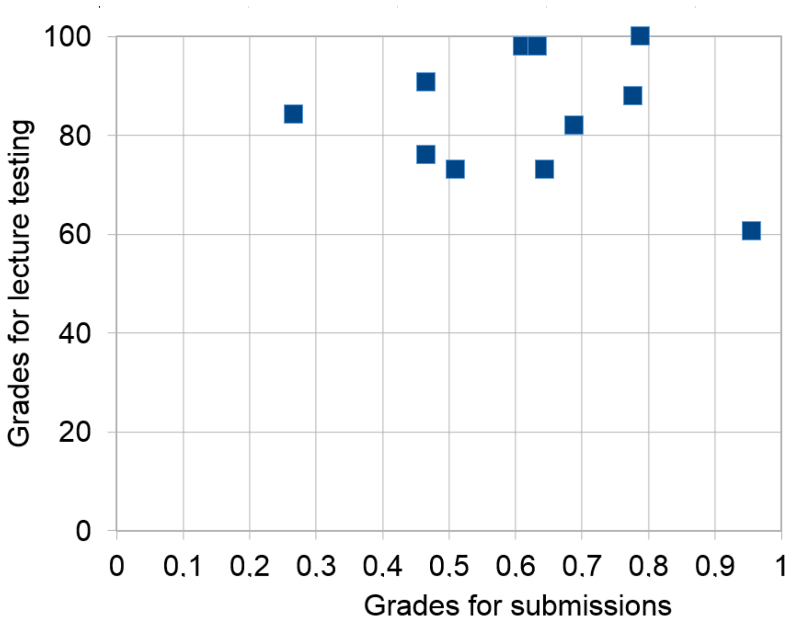

Figure 8: Correlation between students' average grades for submissions and average of the highest grades for lecture testing (future computer science bachelors).

us to check if there was any correlation between students' results in creative work with their program development or testing (high levels of students' independent work management) and results in lecture studying that was managed directly.

Figure 8 shows that there is no correlation between students' submissions and their lecture testing results. Direct management ensured a high level of students' mastery in educational

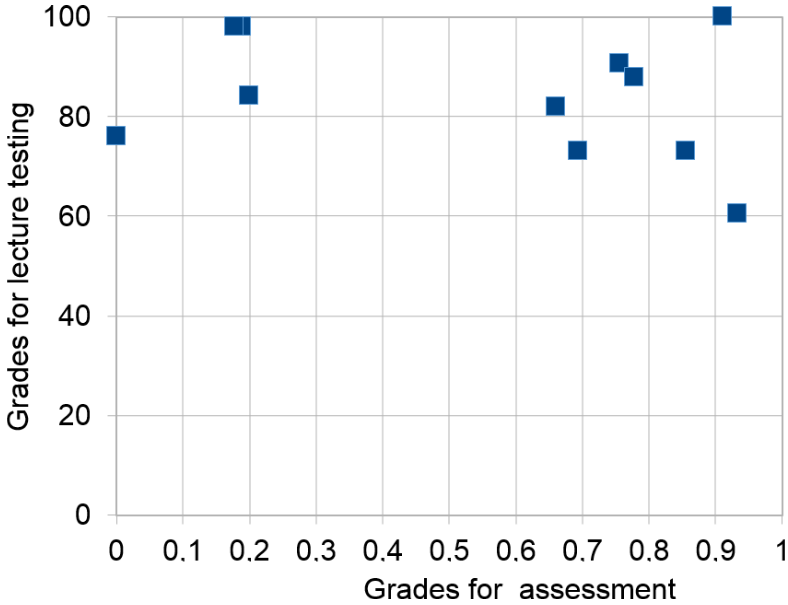

Figure 9: Correlation between students' average grades for assessment and average of the highest grades for lecture testing (future computer science bachelors).

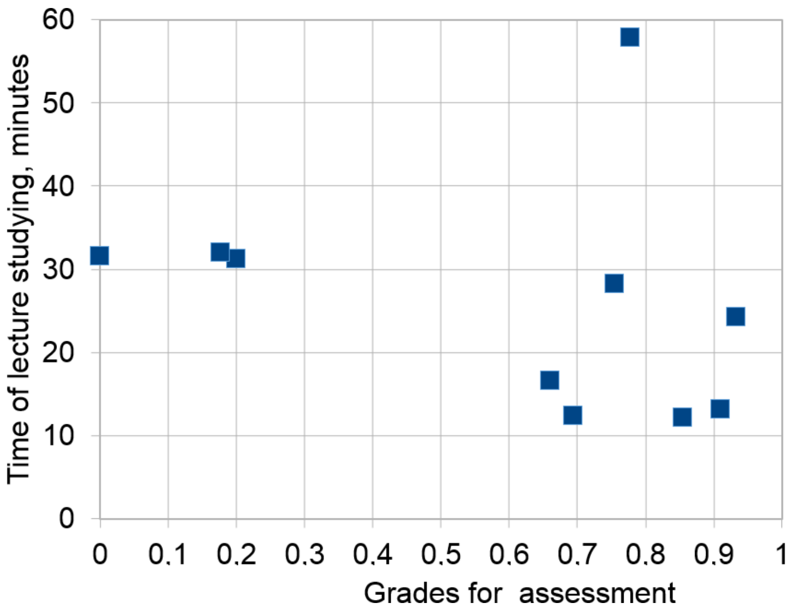

Figure 10: Correlation between students' average grades for assessment and the average time that they used for lecture studying and testing (future computer science bachelors).

material, regardless of their results in program development. Moreover, some students with high proficiency in programming did not pay enough attention to obtain the maximum grade for this type of educational work. A similar pattern is observed when analyzing the correlation between students' grades for assessment and their lecture testing result (figure 9). There is no correlation between students' grades for assessment and the average time that students used to complete a lecture with built-in tests (figure 10). Thus, we can conclude that introspection did not influence the efficiency of directly managed educational activity.

5. Conclusions

Our empirical work, underpinned by pedagogical observations, demonstrated that the provision of theoretically grounded pedagogical conditions for managing students' educational activity led to enhancements in the educational process within the realm of programming. We implemented a flexible management approach for students' educational activity, which involved a timely transition from direct management to co-management and subsidiary management. Our observations indicated that such methods bolstered the efficiency of learning.

The analysis of the experimental data, within the context of our theoretical framework, led us to the following conclusions:

- We proposed indicators for a student's introspection as a characteristic of their learning activity: 1) a student's success in testing their own programs; 2) a student's success in testing and evaluating the program code of other participants in the educational process. Our pedagogical observations indicated that introspection, measured in this manner, had a positive influence on students' self-management efficiency.
- The competency of students in introspection is crucial both for self-management of their independent work and for solving practical tasks in the field of programming. Therefore, it should be enhanced, and educational tasks should consistently include sub-tasks focused on introspection.
- Some students are not prepared to manage their own learning activity. In such cases, the type of management of a student's educational activity should be timely reverted to direct management. Utilizing direct management of learning activity for students with low competence in introspection provided them with the opportunity to master the educational material.
- Students' introspection did not influence the efficiency of their learning activity under direct management. Moreover, some students with a high level of introspection did not execute tasks under direct management with enough care. Therefore, improving the management of students' independent work from direct management through co-management and subsidiary management to self-management is an important task in the educational process.

Looking ahead, we envision further work in the field of computer-oriented management of students' independent educational activity. This includes developing new methods for students' progression from direct management through co-management and subsidiary management to self-management within information and communication educational environments. We also aim to introduce these methods into various educational disciplines and study pedagogical and psychological conditions to enhance students' motivation for self-management of their own educational activity.

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