

Article

## Automated Knowledge and Achievement Assessment System *MISKANTAS-22* Based on the Neural Network Method

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**Abstract.** Knowledge and achievement evaluation system *MISKANTAS-22* based on density matrix and neural network methods were designed as an advisor to the lecturer for automated evaluation of open-type questions. New type of plugin for Moodle system Essay Plus was created, tested, and evaluated for grading purposes. New type of user-friendly interfaces for lecturer and for student in Moodle system was realized. New concept of test of Essay Plus type was created, tested, and realized. The system allows to evaluate the student's answers in real time regime.

**Keywords:** Miskantas-22; Essay Plus; neural network; assessing system; open question.

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### Introduction

University education in Europe is one of the strongest factors determining the technological progress of society, the realization of new products/ideas and a very strong indicator of culture. The constantly updated knowledge/skills base allows for the creation of new interdisciplinary fields of science, thus realizing the course from classical to progressive teaching subjects. The need to select and balance classical and applied subjects for the teaching program and the need to evaluate the student's answer on a real basis - these two problems have always been relevant in the university system.

Over the past few decades, two popular methods of assessing students' knowledge and skills have become established in higher education: i) the standardized test and ii) the essay-type response to an open-type question.

Using a standardized test survey, the lecturer prepares a question and several answers on the topic of the course he is teaching, which can be ranked. The evaluation can be done by the lecturer individually reviewing the work or with the help of a computer.

First method of testing (standardized test) is popular in contemporary high schools but has many disadvantages: a) it encourages the student to memorize or remember, but not to think, b) learning is focused on training the student's short-term memory, c) a large part of the educational material is unreproducible after half a year. Reinert et al [1] emphasize the automated assessment technologies in education (e.g., computerised multiple-choice tests). Nevertheless, the use of the test is very popular, because the automatic evaluation of student answers saves a lot of time and gives an unequivocal answer about the student's abilities (which, for the reasons stated above, can be far from reality).

Second method of testing (essay-type response to an open-type question) could be titled as the historically proven and well-recommended university testing method. The lecturer prepares an open-ended question (impossible to answer using expressions yes or no), the student writes an essay-type answer in which some knowledge, concept, context, and subject content must be revealed. In Framework for Assessment Organization [2, p.69], the importance of using effective testing is accentuated: it is better not to waste time on any test, it is better that the subject of the task is expressed only in such situations about which several questions can be submitted.

Vingsle [3] argues that the practice of formative assessment is a very difficult, demanding, and challenging task for a lecturer. In a minute-by-minute formative assessment, the teacher must make a decision in seconds. It's a hard work. This is a standard way to evaluate the teaching progress using the hard work of lecturers. As it was before, so now there is only one way for the lecturer to check the answer i.e. to read, rethink and evaluate. This requires subject knowledge, general language knowledge and, in some cases, psychological knowledge. This is a time-consuming process and there may be a significant delay before a response is ready.

Would it be possible to automate the evaluation of an essay-type answer? The answer to such a question has to do with the level at which one wants to implement evaluation without human intervention. It is not possible to evaluate any answer to any question. Reinert et al [1] wrote about Automated Essay Grading (AEG) technologies: they are 'good in theory' (e.g., accurate as people, timewise and financially effective and can enhance feedback). According to the previously stated ideas, it is possible to construct a work task: a) how to organize such a machine and b) how to organize data exchange between recipients. First of all, you need to assess the answer of student in following framework: the grammar and syntax of the general language: number of sentences, structure, grammatical parts, etc. Then you need to find keywords - items that are the basis of the learning subject. Distribution of grammar-sensitive material in student's answer which is overlapped by program subject containing material allow estimating the answer in linear grade scale. In this way, it is possible to form an automatic evaluation system.

This work is devoted to knowledge and achievement evaluation system *MISKANTAS-22* based on artificial intelligence methods. This system was designed as an advisor to the lecturer (not a blind rating system), freeing him from the routine work of checking student answers. Article represents the description of automated system devoted for practical evaluation problems:

- 1) to create user-friendly interface for a lecturer and for a student;
- 2) to create database of language items (Lithuanian and English);
- 3) to create the databases related to the task evaluation;
- 4) to evaluate the Essay Plus answer (free-form answer) to the question;
- 5) to realize the information exchange between lecturer and student.

## 1. Literature Review

Automatic evaluation systems have been spreading rapidly, and thus especially related to the solutions of Artificial Intelligence (AI). There are several conceptions which are important for computerisation of teaching processes: E-learning, Communications, Improving of education through assessment.

### 1.1. E-learning Problem

The sudden spread of e-learning in the world is associated with the covid-19 epidemic (2020-2022), when within a few months it was necessary to reorient from auditorium-based to computerization of teaching process. Jati [4] describe this situation in universities and schools of Indonesia. Problems related to the teaching materials or contents were still solved using Moodle [5], a Learning Platform or course management system (CMS) - a free Open-Source software package designed to help educators create effective online sets of teaching/learning material. Otherwise, full list of new type problems occur: in designing digital material development; preplanning of teaching process, etc, ... , testing and final checking and evaluation. Using the old methods seems ineffective because of the new epidemic rules. Das et al [6] appreciated that online learning is becoming popular for one reason: it allows learners learn anything, anytime, anywhere from web resources.

Lithuanian higher education institutions (HEIs) actively use Virtual Learning Environment (VLE) Moodle [5] in the educational process for two reasons: for the presentation of educational materials as well as for the assessment of the knowledge and achievements of learners. VMA Moodle is built on PHP and MySQL (but also supports other databases) using a modular system structure. Each individual module complements it according to the needs. The active community of VMA Moodle developers constantly improves the system and adds new functions. VMA Moodle systems are integrated into many study programs, and user authentication is implemented in them, which is very relevant when assessing a person's knowledge and achievements.

### 1.2. Communications

Saputri et al [7] wrote about increasing the effectiveness of English teaching when there is a convenient access to ICT. Kizilkaya et al [8] discussed the unique opportunities of the 5G networks which must be related to the framework of Education 4.0. In fact, the presence of a broadband connection and the ability to download, view, and assess the visual and audio material in real time allows the lecturer to undertake evaluation activities, allows to emphasize differences, essential phrases, nuances, and changes in the version.

### 1.3. Automatic Assessment

Current Learning Management Systems (LMSs) are presented for tests. Cutrone et al [9] accented the limited character of LMS: assessment using open questions is impossible for evaluating the students' responses. In that case, lecturer intervention is necessary. Wang et al [10] wrote about several traditional machine learning (AI) methods. Some suitable method for customizing personalized assessment results were presented and discussed. There are two directions: concept of statistical approach and concept of AI approach. Cutrone et al [9] checked that assessment using LMS switched in time scale: from statistical or probabilistic approaches (starting from 1960'ies) to primarily on conceptual understanding,

Table 1. Rating of evaluation objects. Adapted according to Ref.[2,p.69]

| Nature of the Task                                | Assessment Scores |
|---|-------------------|
| Recognising scientifically investigable questions | 10-15             |
| Identifying evidence needed                       | 15-20             |
| Drawing or evaluating conclusions                 | 15-20             |
| Communicating valid conclusions                   | 10-15             |
| Demonstrating understanding of science concepts   | 40-50             |

using Natural Language Processing (NLP) approach or linguistic approach. Lukashenko et al [11] analyse intelligent and adaptive support in computer-assisted assessment systems. Lukashenko et al accented the importance of student model that is used with the aim to adapt the system to the needs of a specific user. Due to different assessment criteria, several classifications of the student model are summarized. Clarke [12] presented an overview - how to create an effective student assessment system and what assessment aspects need to be considered. Proskura et al [13] wrote about aspects of evaluation of distance education. The evaluation score is formed after evaluating individual performance. Therefore, depending on the type of assessment, the objectivity of the assessment varies.

### 1.4. Improving of Education through Assessment

Khonbi et al [14] described the novel assessment system ANCOVA. Traditionally, in all educational institutions, only lecturers evaluate students' answers. Nowadays students are supposed to be responsible for their learning and are able to control their knowledge and achievements. As a result, assessment tasks can also be assigned to the students. Woytek [15] observed the increased role of the teacher in improvement students' motivation and achievements, which are related to accountability and control. As a result, students' internal motivation to learn increases. In Framework for Assessment Organization [2, p.69] some psychological aspects of testing tasks are discussed: to make the tasks as realistic as possible and to reflect in them to some extent the complexity of real-life situations. Table 1 shows the rating values of the assessment objects, which should be considered when constructing the test questions.

De Vries et al [16] examines the Assessment for Learning (AfL) strategy which looks too complicated for many teachers (it requires complex professional competence). Effective AfL can significantly increase the student achievement. Vries expressed the mentioned strategy into four principles:

- 1) a competence-based approach,
- 2) adapting to teachers' needs,
- 3) explaining underlying mechanisms, and
- 4) supporting teachers in acquiring the competences.

Doz et al [17] described the idea of assessing students' mathematical knowledge using fuzzy logic. New assessment model is based on use of fuzzy logic that integrates teacher-assigned math grades with students' results according to the Italian national math assessment Knowledge (INVALSI). In this way, the results are much worse than when assessed traditionally by the teacher. Das et al [6] confirm that assessment system can find the self-learning gaps of learners and improve the progress of learning. Yang et al [18] described a Knowledge Connection Analyzer (KCA) with formal testing capabilities. Students with low prior achievement can any time perform a reflective assessment of their knowledge in collaboration with the others, thereby improving their capabilities. Maksymov et al [19] analysed the problem of comprehensive assessment for monitoring student knowledge using ontology methods: the relationship

between explicit and implicit knowledge and skills must be evaluated (program *SvitOsvit*).

### 1.5. Open Question: *pros* and *cons*

Assessment of the response to an open-ended essay-type question can be treated as a part of formative assessment. In our understanding, formative assessment is a process aimed at gathering evidence about student learning and self-learning and using it to improve teaching and learning. This is not just an easy response assessment. Formative assessment is defined as reciprocal response, feedback provided in the educational process, collection, and accumulation of information about learning processes and results, interpretation and use to ensure the quality of teaching and learning. Vingsle [3] indicates that learning outcomes are significantly good, when a lecturer uses formative assessment in his audience. Das et al [6] described tool for automatic question generation from learning resources. In automated assessment system primary task will have estimated using several fixed criteria which allows to measure the correctness of the generated questions: relevance, question type, grammatically correct, and ambiguity. Cutrone et al [9] accented the benefit of the open-style questions. This type of control creates the situation for student to form a response without the comfort of recall words and/or phrases. Usage of open-style questions for control shows that teaching material is well adjusted and prepared according to the high level of Bloom's taxonomy [20-21]. Messick [22] formulates the sentence about the role of cognitive abilities which play or ought to play in educational achievement testing. Proskura et al [13] use the Bloom's Taxonomy levels methodology for the assessment system, for example, by formulating practical tasks (undergraduate course in computer science). Several low-lying levels (remember, understand, apply) could be involved into simple test type assessment, but high-lying levels (analyse, evaluate, create) must be estimated as an objects of open-question type systems.

### 1.6. Summary of Review

Now we can summarize the main prepositions of assessment problems which were analysed in observed publications.

Firstly, technical capabilities must be guaranteed to organize a continuous unlimited LAN/4G/5G connection between the institution's server and the lecturer and students, which would provide video/audio educational material, virtual reality realization and knowledge testing interfaces.

Secondly, teaching material must be presented in well adjusted manner which allows to organize formalized session of two types: test type as well as open question - open answer type.

Thirdly, lecturer must understand the main principles of Bloom's taxonomy for each stage of testing, and to use it in own practice for creating the teaching material as well as for creating the test system.

Fourthly, lecturer is supposed to understand the main principles how to improve the teaching material through feedback. Taken together, the learning speed of individual student is an aspiration that can only rarely be realized without the intervention of the systems of artificial intelligence (AI). If collective education is the main type of auditorium education, it is important that the lecturer adjusts the presented material according to the speed of perception and gaps in perception.

Fifthly, open-type questions aim to assess students' integrative knowledge and abilities when the relevant program topic is mastered.

## 2. MISKANTAS-22: Idea and Realization

### 2.1. Task of Open Type and Assessment

Test-type tasks (one question and multiple answers, of which one or more are correct) are valuable because they allow quite easy computerization of the assessment process. In the correspondingly implemented graphical interface, the server presents a requested number of questions in a set order and collects, ranks, and estimates the answers. A bad feature is that it is impossible to recognize the student's intellectual contribution to the answer. Because of this, open type questions are organized where the student have to write an essay for the answer. The idea of evaluation a submitted essay is based on these definitions.

**Preparation of open question.** Three stages must be realized.

Firstly, a lector is to prepare the task containing an open type question for the students. An answer to the question must be given by using plain text but not one or more words, e.g. Yes or no. This question will be presented to students.

Secondly, lecturer also prepares own answer to this question. The answer remains in the system only for evaluation purposes. The lecturer selects key words and key-phrases (words representing main idea of the subject) from his answer. Using copy/paste method, lecturer forms two column tables of keywords and key-phrases. Lecturer's answer, keywords and key-phrases will not be shown to the student.

Thirdly, student must present the own essay using clear excellent language containing pure grammar forms and any slang words etc. A significant number of sentences must be ordered and submitted (for example, 20-30, depending on the situation). Answer using only a few words (yes, no) or a single sentence without a subject or preposition must be rejected immediately. The main condition for the student is to write the answer in correct sentences (up to about 30 words) that contain a subject, a predicate and several circumstances.

**Formalization of answer.** Three stages must be realized.

Firstly, essay presented by student must be divided into sentences according to the grammar rules. This means that punctuation marks as point, multipoint, question mark, exclamation mark play important role in present routine operation.

Secondly, a set of sentences presented by a student must be divided into words (items) according to the grammar rules. This means that punctuation marks as whitespace, comma, semicolon play important role in present routine operation. After that, following rectangular matrices - one of string type  $S_{m,n}$  and four of integer type  $A_{m,n}$ ,  $B_{m,n}$ ,  $C_{m,n}$ ,  $D_{m,n}$  - were created where  $m$  represents number of sentences in answer, and  $n$  represents the number of items in the sentence containing the maximal number of items:

$$A_{m,n} = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m,1} & a_{m,2} & \cdots & a_{m,n} \end{pmatrix} \quad (87)$$

Initially,

$$s_{ij} = "", \quad a_{ij} = b_{ij} = c_{ij} = d_{ij} = 0 \quad (88)$$

where  $0 \leq i < m$  and  $0 \leq j < n$ . String matrix  $S_{m,n}$  is filled with decapitalized elements (words or items, where uppercase characters were changed by lowercase) and all punctuation is deleted. If the length of current row is less than maximum maximal number of items, last elements were left as empty,  $s_{ij}=""$ .

Thirdly, analysis of items (including different grammar forms) using language dictionary must be provided. For such purposes,

most frequently used dictionaries of Lithuanian language and English language were prepared. Dictionary of language was prepared as DB containing tables: noun, numeral, verb, adjective, adverb, pronoun, particle. For many forms, singular and plural forms are presented. For nouns, numerals, adjectives, corresponding English tables are simply compared to Lithuanian ones, since in Lithuanian inflected forms must be recognized as a separate word. Total scanning of matrix  $S$  and search in the language dictionary tables allows us to fill the matrix  $A$ : if item  $s_{xy}$  is present in dictionary then ( $a_{xy}=1$ ). By default, item  $s_{xy}$  is absent and  $a_{xy}=0$ .

Fourthly, each sentence is validated in the grammar framework: with the necessary presence of the subject and the predicate. Total scanning of matrix  $S$  and search in the language dictionary tables allows to fill the matrix  $B$ : item  $s_{xy}$  is present in corresponding dictionary (noun, numeral, pronoun for the subject or verb for the predicate). Final confirmation occurs by finding a pair of items of the subject and the predicate in the language's two-item table. In that case,  $b_{xy}=1$  for each item.

Fifthly, each sentence is validated in the framework of keywords and key-phrases which were prepared by a lecturer. Corresponding matrices  $C$  for keyword items (single item) and  $D$  for key-phrases items (two or three items) will be filled:  $c_{xy}=1, d_{xy}=1$ .

Sixthly, after completing the mentioned matrices  $A, B, C, D$ , it can be formally assessed that the student:

- a) used words from the general vocabulary of the language of the module,  $A \neq 0$ ,
- b) created sentences that are grammatically correct (contain subject and predicate),  $B \neq 0$ ,
- c) used the keywords and key-phrases of the teaching subject which are essential in present case (defined by lecturer),  $C \neq 0, D \neq 0$ .

If all elements of any row of matrix  $B$  contains 0, it means that corresponding sentence is incorrect (subject or predicate are absent). Corresponding items must be deleted from  $S$  matrix, corresponding sentence must be deleted from answer, and formal filling of matrices  $S, A, B, C, D$  must repeat again.

**Estimation of answer.** Two innovative methods: density matrix (DM) method and AI-based unidirectional neural network (NN) method could be used for assessment, and two grades  $P_1$  and  $P_2$  are counted respectively. Using human intelligence, lector must decide which estimation trends to real grade.

Let us start from consideration that answer of lecturer will be closed to ideal and must be assessed using highest grade "ten" (in 10-point system):

$$P_1^{lect} = P_2^{lect} = 10. \tag{89}$$

According to that, real grades of students obtained using DM method  $P_1^{stud}$  and NN method  $P_2^{stud}$  must be calculated using following equations:

$$P_1^{stud} = P_1^{lect} \cdot \frac{S_{x1}^{stud}}{S_1^{lect}}, \tag{90}$$

where  $S_{x1}^{stud}$  represents the scores of student's answer received using DM method, and  $S_1^{lect}$  represents the scores of lecturer's answer received using DM method. Since the student's data is depersonalized, the Moodle administrator of HEI assigns the student an index  $x$  by which the student's information is identified. For current session, only one lecturer answer will be used.

Firstly, to obtain the scores  $S_{x1}^{stud}$  and  $S_1^{lect}$ , mentioned DM method will be used for estimation through the influence of the weight factors to matrices  $A, B, C, D$ . Established empirically, following four criteria must be fulfilled:

- a) weight factor  $w_1$  for item which is present in language dictionary;
- b) weight factor  $w_2$  for item which is present in pair of subject and predicate;
- c) weight factor  $w_3$  for item which is labelled as a keyword;
- d) weight factor  $w_4$  for item which is labelled as an item from key-phrase.

The biggest problem is to select the correct coefficients according to the prior criteria for the presence of the item - i.e., rational weight coefficients  $w_1, w_2, w_3, w_4$ . For  $P_1$  estimation, we decided to use empirically established weight coefficients:

- $w_1 = 1$  (item in language dictionary),
- $w_2 = 3$  (item in pair of subject and predicate),
- $w_3 = 5$  (item labelled as a keyword),
- $w_4 = 10$  (item labelled as an item from key-phrase).

$$A_{m,n}^* = w_1 \cdot A_{m,n} \tag{91}$$

$$B_{m,n}^* = w_2 \cdot B_{m,n} \tag{92}$$

$$C_{m,n}^* = w_3 \cdot C_{m,n} \tag{93}$$

$$D_{m,n}^* = w_4 \cdot D_{m,n} \tag{94}$$

Finally, scores for student answer  $S_1^{stud}$  as well as lecturer answer  $S_1^{lect}$  will be calculated using equation:

$$S_1 = \frac{1}{N_S} \cdot \sum_{i=0}^m \frac{1}{N_R} \left( \sum_{j=0}^n (a_{m,n}^* + b_{m,n}^* + c_{m,n}^* + d_{m,n}^*) \right) \tag{95}$$

where  $N_R$  represents number of items in current sentence and  $N_S$  represents number of sentences (in answer of lecturer as well as student respectively).

Secondly, to obtain the grade  $P_2^{stud}$ , mentioned NN method will be used. Unidirectional neural network (NN) (input layers -  $L=4$ , hidden layers -  $M=100$ , output layers -  $N=1$ ) is presented in Fig. 1. Programming module was constructed in traditional object-oriented programming manner using two typical classes from source [23].

Two NN modes were used: training and prediction. 10,000 epochs were used for the NN training mode. NN training was performed using excellent response (answer) of lector, and corresponding grade by default  $P_2^{lect}=10$ : four input layers (matrices  $A, B, C, D$  which correspond to the lecturer's answer) and one output layer (grade  $P_2^{lect}=10$ ).

For the NN predicting mode, the student's far-from-perfect response data was used: four input layers (matrices  $A, B, C, D$  which correspond to answer of student) and one output layer (grade  $P_2^{stud}$  which is an object of NN prediction). Finally, grade  $P_2^{stud}$  can be received in the interval (0;10).

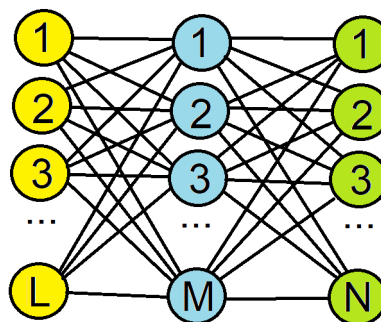


Fig. 1. Unidirectional neural network (NN): input layers -  $L=4$ , hidden layers -  $M=100$ , output layers -  $N=1$ .

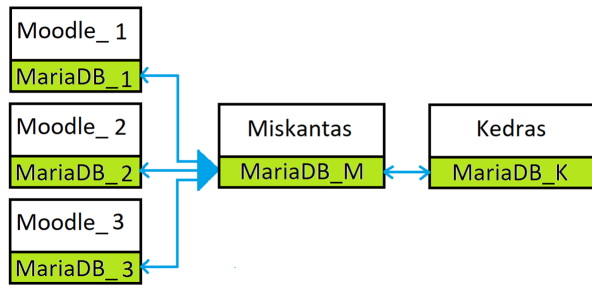


Fig. 2. General schema for information exchange between several DBs: MariaDB<sub>k</sub>, k=1, 2, 3, ... , belong to corresponding Moodle<sub>k</sub> of different HEI. Miskantas contains its own MariaDB<sub>M</sub> for collection of answer data into sessions (center). Kedras contains its own MariaDB<sub>K</sub> for information development (right).

## 2.2. General Schema

The MISKANTAS-22 evaluation system is an advisory tool designed to streamline the teacher’s routine task of assessing student responses in real-time or upon request. MISKANTAS-22 falls under the category of Learning Management Systems (LMS) and Natural Language Recognition (NLR) systems, developed using the best practices of Automated Essay Grading (AEG) technologies. The MISKANTAS-22 system comprises multiple modules and frameworks: a) the newly created Miskantas system for concentrated data collection in the database (DB). b) the newly created Kedras system for evaluation and assessment. MISKANTAS-22 can be utilized by one or several higher educational institutions (HEIs), regardless of their location. Each institution (such as an institute, department, faculty, school, etc., briefly referred to as HEI) should maintain its own

Moodle system based on Maria DB [24], which is an open-source database with database-as-a-service solutions to ensure scalability. The VMA Moodle system is known for its exceptional flexibility and reliability. After evaluating the advantages of the VMA Moodle system, including its flexibility and reliability, the decision was made to implement the developed system as a VMA Moodle plugin. The databases used in Moodle systems were studied, and Maria DB was chosen as the most suitable option for the developed system. While there are many similarities between the MariaDB and MySQL database management systems, MariaDB stands out for its performance improvements, better testing, and fewer errors. The Moodle system should be deployable within any institution’s location and can also make use of cloud solutions.

The MariaDB which belongs to HEI Moodle must be linked to MariaDB<sub>M</sub> of Miskantas system, which collects non-personalized materials presented by HEIs for evaluation. When a session is completed based on time-limit criteria (all student answers are gathered in the intermediate MariaDB<sub>M</sub> of Miskantas), the Kedras module initiates several step-by-step operations:

- a) data is transferred from MariaDB<sub>M</sub> of Miskantas to MariaDB<sub>K</sub> of Kedras,
- b) evaluation of student answers takes place,
- c) data is transferred from MariaDB<sub>K</sub> of Kedras to MariaDB<sub>M</sub> of Miskantas,
- d) data is transferred from MariaDB<sub>M</sub> of Miskantas to corresponding MariaDB at HEI Moodle.

Following this, the lecturer must assess the received result and communicate it to the students through routine operations. Fig. 2 illustrates the general scheme of information exchange among various databases: multiple HEIs, Miskantas, Kedras. Fig. 3 depicts the principal scheme of information exchange, including the working modules, among various databases: multiple HEIs, Miskantas, Kedras.

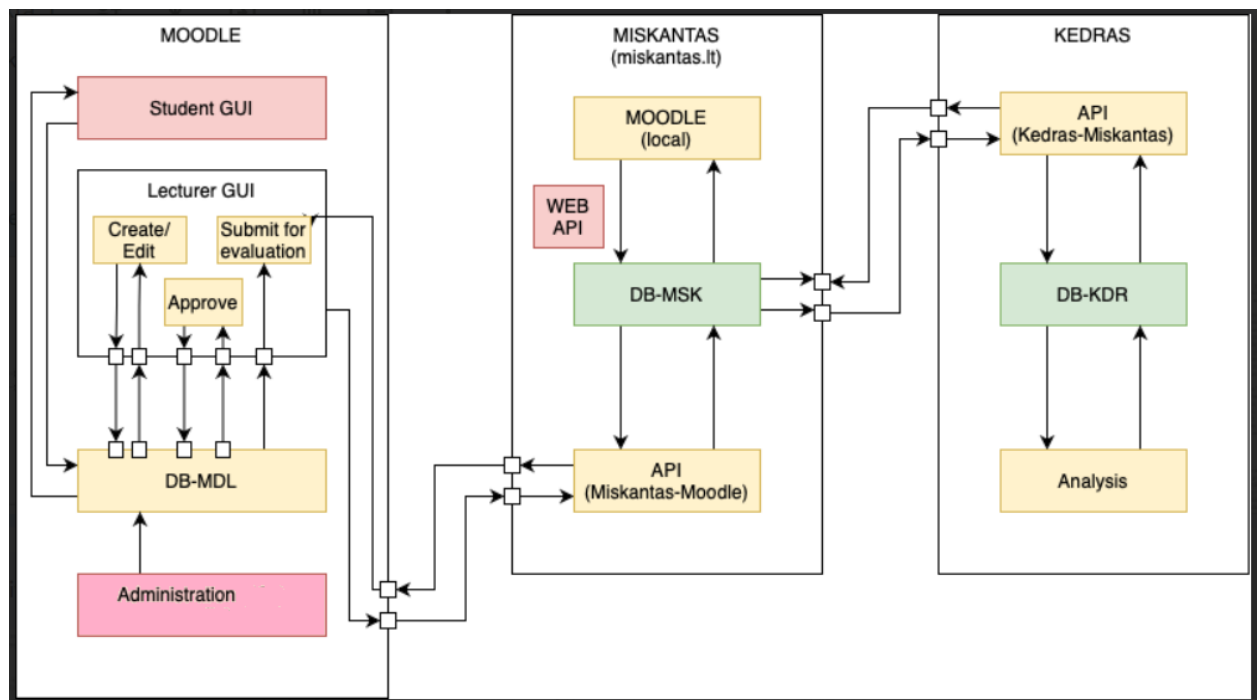


Fig. 3. Principal scheme of information exchange between DB of several subjects: several HEIs, Miskantas, Kedras with working modules.

### 2.3. Roles of Responsible Individuals

Active individuals with clearly defined roles are essential participants in these activities. The following individuals are involved in this process: the Moodle Administrator of the HEI, the HEI Lecturer, the HEI Student, the *Miskantas* Administrator, and the *Kedras* Administrator.

**Administrator of Moodle at HEI.** The Moodle administrator of any HEI contacts the *KEDRAS* administrator to request a connection certificate for *KEDRAS* access, either for commercial or testing purposes. Additionally, the Moodle administrator creates user accounts within Moodle for both students and the lecturer belonging to the relevant program group. Furthermore, certain significant modifications need to be made in the HEI's Moodle system. The Essay Plus plugin for the *Question* type, provided by the *KEDRAS* administrator, must be installed within the HEI's Moodle system. These changes should be implemented within the *Question* subsystem module.

**HEI Lecturer.** Upon registration in the Moodle system, the HEI lecturer begins preparing an Essay Plus type task. The task comprises the following components:

- a) an open-form question,
- b) an open-form question answer,
- c) a list of keywords, copied and pasted from the answer,
- d) a list of key-phrases, copied and pasted from the answer.

The preparation can be completed using any text editor, with the input process carried out through Moodle's graphical interface designed for lecturers. The language used in the task must align with the educational program, whether in Lithuanian or English. The Essay Plus type task can be formulated in either English or Lithuanian. The lecturer is responsible for indicating the language of the task. Subsequently, the relevant language's general vocabulary will be associated. The lecturer must bear in mind that Blum's taxonomy categories [20-21] guide effective assessment practices: lower levels (remember, understand, and apply) are suitable for simple test-type evaluations, while higher levels (analyze, evaluate, and create) can be incorporated into open-form tasks.

The lecturer's task for the Essay Plus type should be designed in a manner that prevents one-word answers such as "yes" or "no." The answer should be provided in plain text format. Towards the conclusion of the question, the lecturer should specify the desired number of sentences in the answer, with an optimal range of  $10 < X < 30$ . Each student will receive the Essay Plus type question at the appropriate time through the Moodle system when accessing their account.

The lecturer composes the answer to their question, consisting of 10 to 40 sentences in plain text. This response is stored within the Moodle system and remains concealed from students' direct view or access. The lecturer's answer is assigned a preliminary evaluation of ten points. The lecturer holds the responsibility of ensuring that this answer serves as an exemplary model, encompassing fundamental elements that define the question's content and expression.

The lecturer selects keywords and key-phrases (copied and pasted) using their account's interface. These selections are deemed necessary by the lecturer to capture the essence of the answer. Both keywords and key-phrases are stored within the Moodle system, out of direct sight and access for students.

The lecturer must choose keywords in their standard grammatical form. For instance, nouns and adjectives should be in the singular nominative case, while verbs should be in their base form. These keywords should not include particles, conjunctions, prepositions, adverbs, or jargon. They can, however, be drawn from a subject-specific dictionary, but the *Kedras* administrator should be

informed of this in advance. Words from specific vocabulary such as C++, JAVA, SQL keywords can also be used as the keywords of task of Essay Plus type. The ideal range for the number of keywords is  $10 < X < 50$ .

Additionally, the lecturer should select key-phrases as they are provided in the lecturer's answer. A key phrase may consist of two, three, or four words, but it should not include particles or conjunctions. The optimal quantity of key phrases should fall within the range of  $10 < X < 30$ . The keywords and key phrases chosen by the lecturer will play a crucial role in the automated evaluation of the student's response.

**HEI Student.** The student(s) should provide a free-form answer to the Essay Plus type question using the Moodle interface. Students must comprehend that their answers will be assessed based on correctly grammatically structured sentences, devoid of jargon words. A sentence is defined as a group of words ending with a period, question mark, or exclamation point. The answer should be presented in the language of the task, rather than any language. Elements that are not present in the task language's dictionary will be disregarded. However, keywords are an exception, as they are explicitly provided by the lecturer as necessary words, even if they are not part of the dictionary.

The student's response must be composed in plain text. A minimum criterion for sentence correctness is the presence of coherent structure and proper pronunciation. In their answer, students are required to demonstrate an understanding of the question. The formal response should relate to the evaluation routine and potential application possibilities.

**Administrator of *Miskantas*.** Upon receiving a request from the Moodle administrator of the HEI for a login certificate, the Administrator of *Miskantas* issues a time-limited *Miskantas* connection certificate for the HEI. This certificate includes specific details regarding the mode of testing or activity, assessment quantity, and the applicable time interval. Additionally, the Administrator of *Miskantas* provides the Moodle plugin for the Essay Plus type in accordance with the *Miskantas* connection certificate granted to the HEI.

**Administrator of *Kedras*.** The Administrator of *Kedras* oversees the development and logic of general language dictionaries (both Lithuanian and English). Additionally, this administrator is responsible for supervising the creation and logic of specialized dictionaries, which are requested by HEIs based on the *Miskantas* connection certificate.

### 2.4. Dynamics of System

The dynamics of the system can be divided into eight stages, which are described as follows.

**1st stage.** The authority of the HEI determines that the *Miskantas* service is essential for learning, teaching, and assessment purposes. Subsequently, they acquire the *Miskantas* license, which outlines details such as the number of languages, testing intervals, assessment modes, and quantity.

**2nd stage.** Based on the *Miskantas* connection certificate for the HEI, the Moodle administrator of HEI installs the Essay Plus type Moodle plugin.

**3rd stage.** A lecturer at the HEI chooses to assess students' knowledge. They create a Moodle test that can encompass various question types available in the system, including Essay Plus type questions. If an Essay Plus type question is part of the test, it should include a correct answer provided by the lecturer, along with lists of keywords and key-phrases. All this content is uploaded to the HEI's Moodle system.



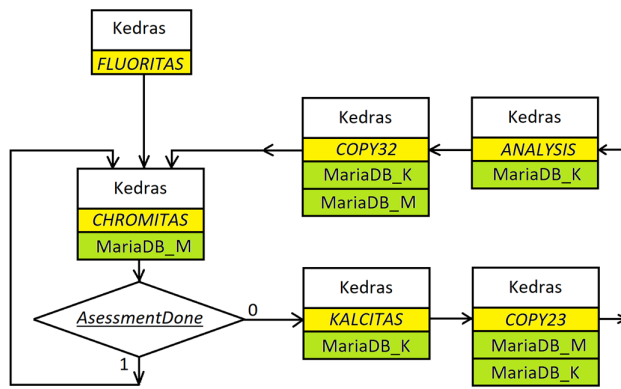


Fig. 4. Principal scheme of package *Kedras*.

**4th stage.** Following the lecturer's instructions, students gain access to the test at the designated time and complete it. Students only view the open-type question and are able to input their own responses. The answers provided by students are saved in the HEI's Moodle system. The lecturer's answer, as well as the lists of keywords and key-phrases, remain invisible to students.

**5th stage.** At this point, the system's activity commences. It becomes necessary to group the collection of answers associated with a particular open-type question. For example, in an academic group of 20 students, if only 18 students submit answers, these responses, along with the lecturer's answer, keywords, and key-phrases, are combined into a single entity called a "session." At the conclusion of the test duration, the lecturer triggers the transfer of the session object from the HEI's MariaDB to the *Miskantas*' MariaDB\_M using *API-Copy12*.

Fig. 4 illustrates the principal scheme of the *Kedras* package, composed of modules *Fluoritas*, *Chromitas*, *Calcitas*, *Copy23*, *Copy32*, and *Analysis*.

Module *Fluoritas* (initiated and halted via the command line) triggers the checking of the MariaDB\_M database. Module *Chromitas* scans the MariaDB\_M of *Miskantas* at predefined time intervals. When records corresponding to unassessed sessions (with the parameter *AssessmentDone=0*) are located, module *Calcitas* instigates the transfer of data from MariaDB\_M of *Miskantas* to MariaDB\_K of *Kedras* utilizing the *API-Copy23*.

Allow me to elaborate further. Inside module *Fluoritas*, a for() loop is established, ranging from 1 to 1,000,000 with an increment of 1. Enclosed within this loop is the sleep() method, which introduces an activity delay of 1 minute per cycle (this interval can be adjusted up to 1 hour). After the delay, the subsequent call is made to module *Calcitas*, which scans the session table in MariaDB\_M of *Miskantas*. If only records corresponding to assessed sessions (where the parameter *AssessmentDone=1*) are found, the activity exclusively proceeds within the for() loop.

In contrast, if one or more records are encountered that correspond to unassessed sessions (with *AssessmentDone=0*), a sequence of four modules are activated in order: *Calcitas*, *Copy23*, *Analysis*, and *Copy32*. These modules facilitate the exchange of data between MariaDB\_M of *Miskantas* and MariaDB\_K of *Kedras*. Specifically, *Copy23* facilitates the initial data transfer in a forward direction, while *Copy32* handles the transfer of resulting data in reverse. Upon the completion of these operations, module *Chromitas* is called once more, resuming its task of scanning the session table in MariaDB\_M of *Miskantas* at appropriate intervals. The purpose of this scan

remains consistent: to identify any newly unassessed sessions at the present time, where the parameter *AssessmentDone=0*.

**6th stage.** Module *Analysis* undertakes assessment utilizing two distinct methods: the density matrix (DM) approach and an AI-based unidirectional neural network (NN) approach. Two grades,  $P_1$  and  $P_2$ , are calculated for the lecturer's reference. Before initiation, certain information must be incorporated into MariaDB\_K of *KEDRAS*, including:

- the session object, encompassing the task with an open-type question, the lecturer's Essay Plus type answer, the corresponding lists of keywords, and key-phrases,
- multiple students' Essay Plus type responses,
- language dictionaries (English or Lithuanian) as requested by the lecturer.

Module *Analysis* comprises two submodules: *Read\_sessions()* and *Do\_Sessions\_Tasks()*. Intermediate data may be prepared, for example, a student's answer in \*.docx format with highlighted items corresponding to keywords and key-phrases. The outcome of this process is summarized as follows.

For student XXX's answer:

number of grammatically correct (valid) sentences: 18

(containing subjects and predicates),

number of evaluated sentences containing keywords: 12,

number of evaluated sentences containing key-phrases: 8,

DM-generated grade:  $P_1 = 7.2$ ,

NN-generated grade:  $P_2 = 6.4$ .

Using *Copy32*, the resulting data is transferred backward between MariaDB\_K of *Kedras* and MariaDB\_M of *Miskantas*.

**7th stage.** The result generated by the computer is transferred from MariaDB\_M of *Miskantas* to the Moodle's MariaDB of the HEI using the *API-Copy21*. Initially, only the lecturer possesses the capability to review the received results. The lecturer acquaints themselves with the evaluations and subsequently either confirms them or makes necessary corrections. These confirmations and corrections are conducted manually, involving the activation of corresponding checkboxes.

**8th stage.** The lecturer provides their approval for the assessments, incorporating any corrections they have made. Subsequently, the students of the HEI gain access to the assessments endorsed by the lecturer.

Comments provided to students encompass the final grade determined after the lecturer's review (where the lecturer has the authority to modify the advisory system's outcome). The comments also include information such as the count of detected sentences, the number of grammatically accurate sentences, and the total number of evaluated sentences. Furthermore, supplementary text derived from the lecturer's response, containing key phrases that weren't employed in the student's response, might be included.

## 2.5. Moodle: Input/Output Interface for Lecturer

In the current system, a new form of information input was developed within the Moodle framework. Alongside the existing Test and Essay interfaces, a novel plugin named *Essay Plus* was conceptualized, created, and tested specifically for discussion-type questions. Tasks falling under the *Essay Plus* category are open-ended questions, distinct from standard tests, and are derived from the relevant syllabus, in response to students' requests.

Lecturers create a QUIZ activity within the Moodle of the HEI. If the decision is made to craft any form of test, after the installation of the *Essay Plus* plugin, the *Essay Plus* type will appear within the

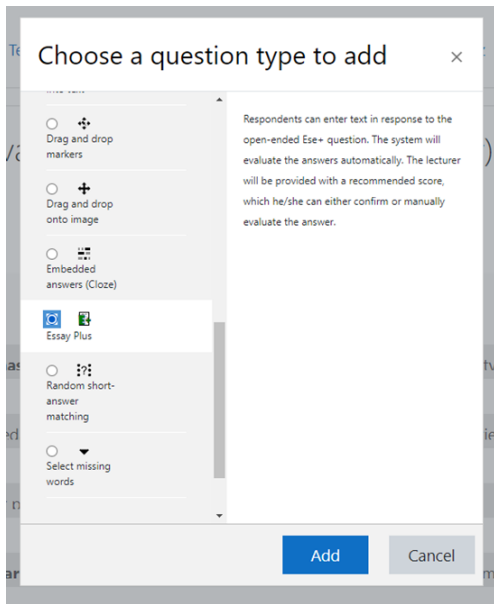


Fig. 5. Moodle of HEI, window of selection of test type. An Essay Plus type is activated.

list. Fig. 5 illustrates the Moodle graphical interface, featuring a window for selecting the test type, with the option for activating the Essay Plus type at the bottom. Fig. 6 represents the interface intended for lecturers to create an Essay Plus test. This involves five essential fields:

- 1) question name,
- 2) open-form question,
- 3) answer to the open-form question,
- 4) list of keywords, and
- 5) list of key-phrases.

Lecturers can introduce questions to the test, which could be either freshly formulated or sourced from a pre-existing question bank.

Upon students taking the test, the lecturer instigates a review of Essay Plus question sessions. This action is manually conducted

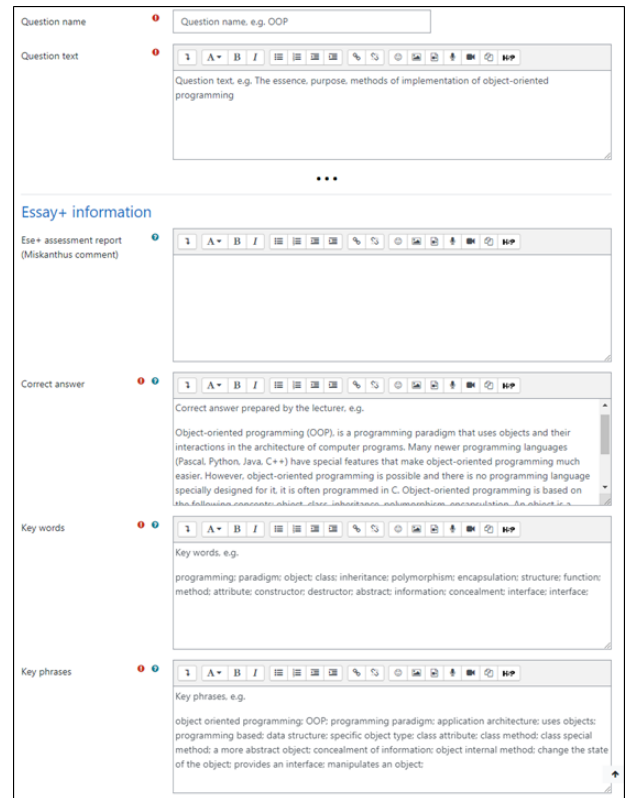


Fig. 6. Moodle of HEI, test of Essay Plus type. Interface for lecturer: required fields for question name; open form question; answer to open form question; list of keywords; list of key-phrases.

within the test report window, either immediately after the test or subsequently, at the lecturer's convenience. Fig. 7 showcases the QUIZ activity window containing the interface for the lecturer, along with options for triggering the checking routine: "Submit All Essay Plus Questions" or "Submit Selected Essay Plus Questions". The checking routine follows the data exchange process across corresponding MariaDBs, as outlined previously. The system also facilitates conventional assessment of students' Essay Plus questions.

Upon evaluating questions of Essay Plus type, *Kedras* automatically transmits the results back to the Moodle of the HEI. When the lecturer revisits the test report window, the returned system evaluations become visible. The status of each student's answer is represented by the Essay Plus icon (marked with E+), appearing in varying colours. Gray indicates that the automatic evaluation of the question hasn't commenced, yellow signifies that the evaluation is in progress but incomplete, and green indicates successful evaluation. The lecturer then proceeds to either approve the grades or manually correct them. Following this standard procedure, the option to publish results to students becomes available. Fig. 8 showcases the QUIZ activity window, featuring the Essay Plus interface for the lecturer, complete with information about the present status of questions. The yellow and green icons denote different question statuses.

In scenarios where several students didn't participate in the Essay Plus test session, a common situation might arise. If previous results of the absent students have already been disclosed, it is possible to organize an additional session to assess new submissions. This process of re-evaluation of the session(s) can be initiated similarly.

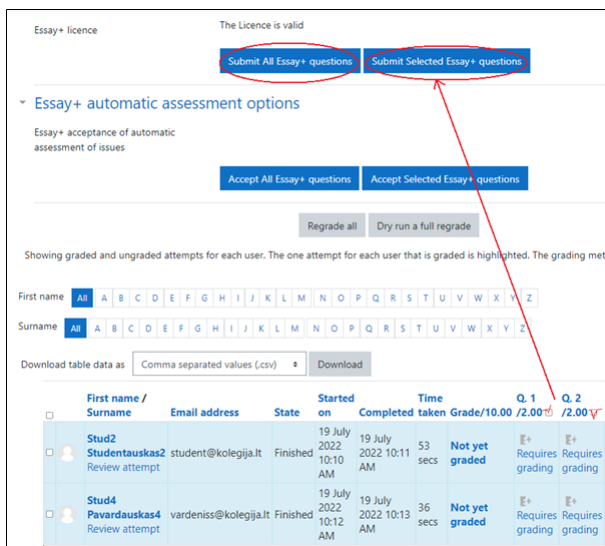


Fig. 7. Moodle of HEI, window of QUIZ activity. Interface for lecturer: activation of checking routine.



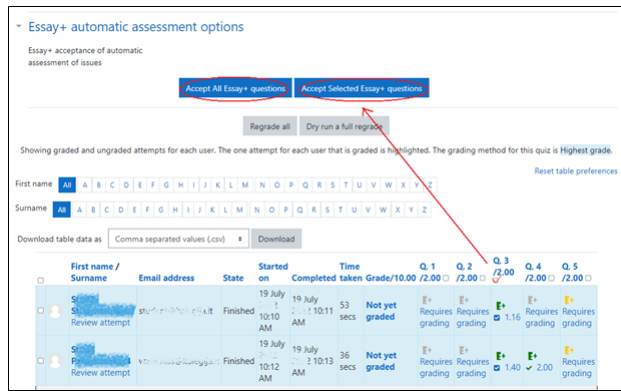


Fig. 8. Moodle of HEI, window of QUIZ activity. Essay Plus interface for lecturer. Current situation: state mapping.

## 2.6. Moodle: Input/Output Interface for Students

The lecturer communicates to the students about their participation in the Essay Plus type test within the HEI's Moodle system. During the test, students respond to the Essay Plus question by inputting plain text into the designated text-entry window. Fig. 9 showcases the Essay Plus interface tailored for students, prominently featuring the open-form question at the top.

Required field for answer to open form question is prepared, and student generate an answer. Fig. 10 represents a report window, which is presented before the test is fully graded. After taking the test, when the test is graded, the student sees the test results in the test taking window. Until at least one question of the student's test is evaluated, he does not see the test taking report and the results.

## 2.7. One Answer Story

Test of Essay Plus type (in English) prepared by lecturer Andrejus Račkovskis is presented below. Session content of Essay Plus type test was send to automatic assessment using English dictionaries. The main problem as recognition of words of various grammatical forms was successfully solved.

**Question of open type:** Every country in the world has problems with pollution and damage to the environment. Do you think these problems can be solved? Write an essay giving reasons for your point of view. Write about: 1) transport; 2) rivers and seas; 3) your own idea.

**Answer to question of open type (lecturer answer):** If we surf the web looking for pollution and environmental catastrophes, we will find out that every country in the world suffers them. This is a natural consequence of the struggle between development and environment. If a country decided to live isolated from the rest of the world, living on what it can naturally grow and produce, it surely wouldn't be highly polluted. But we all want exotic food and technological items from all over the world, so we have to pay the price. Investing in electrical transport would benefit the environment a lot. Even more if this electricity came from a natural source of energy like wind, rivers, and solar panels. It is difficult to achieve this because petrol companies will fight against these actions. We also have to take care of our rivers and seas. We all have heard about factories throwing highly toxic substances to rivers, without minimizing their poisoning effects. A really strict law should be applied to fine

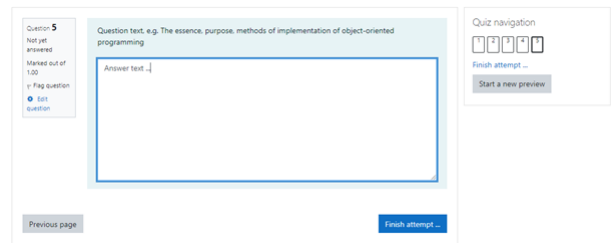


Fig. 9. Moodle of HEI, Essay Plus interface for student: Open form question is presented on top. Required field for answer to open form question.

Grading method: highest grade

| Attempt | Status   | Marks / 4.00   | Grade / 10.00  | Review |
|---------|----------|----------------|----------------|--------|
| 1       | Finished | Not yet graded | Not yet graded | Review |

Highest grade: Not yet graded / 10.00.

Fig. 10. Moodle of HEI, Essay Plus interface for student: Report window, which is presented before the test is fully graded.

these factories and make them change their policy. But what about ourselves? We also can do a lot! If, when possible, we bought larger packs of food, we would be producing less rubbish. And this is only an example!

**Keywords:** pollution; pollute; polluted; struggle; development; produce; environment; environmental; catastrophe; disaster; suffers; electrical; transport; benefit; source; wind; solar; toxic; substance; minimize; poisoning; effect; law; policy; rubbish.

**Key-phrases:** environmental catastrophes; suffer catastrophes; natural consequence; struggle between; naturally grow; naturally produce; highly polluted; pay the price; electrical transport; benefit the environment; natural source; source of energy; solar boards; petrol companies; fight against; take care of; throw toxic substances; highly toxic; minimizing the effects; poisoning effects; a strict law; strict laws; fine factories; change your policy; change their policy; produce less rubbish.

## 2.8. System Malfunctions

System malfunctions were recorded and classified into three groups.

1. Disturbances in the system's work related to the specifics of manipulating the content of general dictionaries. The general dictionaries of the Lithuanian language were compiled according to the frequency principle - i.e., collected the most frequently used words ranked according to Zipf distributions. However, it turned out that such a classical approach (which is very suitable for the English language) is not very suitable for the Lithuanian language, because Lithuanian words have variable endings. As a result, the statistics of the frequency distribution are highly skewed. Dictionaries are very extensive, and searching takes time. It was necessary to divide and redistribute the dictionaries of Lithuanian language according to parts of speech: noun, adjective, verb, etc.

2. System malfunctions related to keywords and key-phrases asked by the lecturer. It is likely that the lecturer knows his teaching subject and understands which words or terms are essential, related to the essence of the question. However, if the lecturer has no experience in constructing the tasks of Essay Plus type, he often inserts non-essential expressions between keywords and key phrases that students do not use or repeat. In this way, the keyword or keyword

phrase becomes informational ballast that needs to be removed. A very simple solution to the problem was invented: when sending a comment to the lecturer, it indicates a keyword and keyword phrase not used in any of the student's answers. In this way, the lecturer has the opportunity to consider the data presented for the next Essay Plus test.

3. Disturbances in the system's work related to the various signs used in the student's answer. Some students intentionally or unintentionally use various non-ASCII characters and non-UNICODE language characters (such as Sanskrit letters, Arabic letters, special characters, etc.) in the answer, which are not recognized by the system. In this way, such a character breaks the search in already compiled dictionaries. The solution devised is a deep digital filter for post-input filtering.

## Conclusions

Analysis of texts written by students (in English and Lithuanian) could be performed automatically (on a semantic and morphological basis using specific dictionaries) and quantitative assessment could also be performed automatically. However, the automatic evaluation according to the previously described algorithms generates a low grade, much lower than what the lecturer would evaluate. It is good that overestimation is impossible. Really, grade "8" could be replaced by "10".

Copy-paste problem is not solved yet. If 60% of content of previous sentence is repeated then current sentence must be excluded due to inner plagiarism. To solve such a problem, it is necessary to create a filter that analyses the word distribution in each sentence not only in relation to its neighbour sentence, but also to all others.

In general, grammatical content is very sensitive: exceptions, deviations from rules, conventions of expression or the use of new terms cause the problems of non-identification or rejection by the system. In some cases, the grammar rules become too fancy, and lists containing all necessary exceptions must to be created.

The problem of synonyms has not yet been resolved. For example, does item *estimation* corresponds to item *assessment* or not? It depends on the context.

Some rules for the teacher must be strictly maintained. When preparing a test of Essay Plus type, the lecturer must not forget the essential elements of Bloom's taxonomy. Ideally, the lecturer's task would be multifaceted and allow to look at the problem from several points of view.

In the process of research, the following main scientific and practical results were obtained as presented below.

1. New type of test of Essay Plus type have been designed, developed, and subjected to evaluation.
2. User-friendly interface in Moodle system devoted to test of Essay Plus type for lecturer and for student has been designed, developed, and tested.
3. Databases of applied vocabulary (Lithuanian and English) have been designed, developed, and tested.
4. Knowledge and achievement evaluation system *Miskantas-22* based on density matrix and neural network methods for automated evaluation of open-type questions was created, evaluated for the purpose of grading.
5. System allows to evaluate the student answers of Essay Plus type in the regime of real time.

## Abbreviations

|         |   |   |
|---------|---|---|
| AEG     | - | Automated Essay Grading                 |
| AfL     | - | Assessment for Learning                 |
| AI      | - | Artificial Intelligence                 |
| API     | - | Application Programming Interface       |
| CMS     | - | Course Management System                |
| DB      | - | Data Base                               |
| HEI     | - | Higher Educational Institution          |
| ICT     | - | Information Communication Technologies  |
| LMS     | - | Learning Management Systems             |
| NLP/NLR | - | Natural Language Processing/Recognition |
| VLE     | - | Virtual Learning Environment            |

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## Authors' contributions

Concept of project was initiated, adjusted and finalised by all authors. V. Jadzgevičienė and G. Čechamirienė prepared the concept and realization of data exchange between different data bases and tasks of tests. G. Čechamirienė initiated the idea and design of Essay Plus type plugin and graphical interfaces in Moodle. A. Gruodis prepared the assessment system *Kedras* (source code in Java). A. Gruodis and V. Jadzgevičienė wrote the theoretical overview, A. Gruodis prepared the next part of practical implementation. All authors reviewed and approved the final manuscript.

## Conflicts of interest

All authors declared at they have no conflicts of interest.

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