Web-based application for self testing and assessment in the field of Microbiology

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Abstract — Several studies conducted in the domain of Web-based education tools have showed students and teachers interest in using Web applications and their added benefits to the professional knowledge development of the students.

Our Web-based application was developed as an educational tool for the purpose of self testing and assessment, allowing an easy evaluation of knowledge and determining the needed improvement areas. It is addressed not only to students and residents in medicine but also to any other category of students, offering the possibility of understanding and refining the theoretical and practical knowledge. The described methodology was experimentally tested in the domains of bacteriology, virusology and parasitology.

The aim of our study was to implement, with low cost, a modern Web-based solution for knowledge assessment and in the same time to make it available and easy accessible to teachers, students and medical residents**.** The implementation of this web-based application offers all the advantages provided by the Web technology (interoperability, multiple users, reusability and extendibility) and will also support these categories in evaluating and extending their knowledge in the field of Medical Microbiology. The design and concept of the application allows its extension in any educational field with minimum effort needed.

The innovative aspect of our application consists in a module that will maintain the objectivity of the assessment process by preserving the same set of questions in the examination form for all the tested students. This feature is provided by creating an examination template, responsible for arranging the questions in a randomized manner and in the same time for switching the order of the response options being presented to the user.

Our application offers great potential for improving the assessment and self-testing of students and residents in medicine and many advantages over traditional assessment methods like: objectivity of the assessment process, larger diversity of tests and of their content, significant decrease of the time spent for the examination, better results in the process of evaluation and scoring.

Keywords **—** Web-based tool, Microbiology, knowledge assessment, online examination system.

I. Introduction

Assessment in education is a complex process with deep moral implications having as ethical consequences the achievement of classifications and selections that will affect the professional and personal development. This represents much more than the measurement of acquired knowledge and marking, having effects in social and individual live [12]. In our days, teacher's interest and attention in following rigorous and high level standards for measuring student achievements has increased. The importance of high-quality Web-based tools for student professional knowledge development is now recognized more than ever in education [8], [18], [24].

The role of assessment and evaluation is multiple and of high importance in the context of comparisons between what was intended in the learning process and what was obtained. The results can be used to stimulate the students' interest for study and to evaluate the efficiency of the educational system in order to reach a higher level of performance [2].

When using the new instructional technology like online learning and online assessment, institutions and teachers have to consider also the professional code and ethical obligations associated with this use.

The most important features for an online evaluation tool discussed in the literature are: diversity, equality, Web accessibility, confidentiality, copyright [16].

The classical assessment methods can lead to disturbances due mainly to the subjectivity of the people implied in the process. This can consist in a wrong appreciation by the teacher of an answer due to a pre-existent impression on the evaluated student or lack of communication, low exigency regarding the difficulties of the tests or in attitudes that can discourage the students. These aspects have an unfavorable influence on the quality of the didactical process through the drop of confidence in the examination [21].

The use of quiz tests allows the removal of the issues due to subjectivity, but has the disadvantage of a longer time needed for the results and of the errors in calculating the score. On the other side, computer-based automation of these tests enables a wider diversity of the question content, increase in results accuracy and significant decrease of the overall examination time, including time spent for the examination, scoring and communication of the results [7], [23].

Researches performed in the field of computer-based versus traditional lecture courses have indicated that students are at least as satisfied in on-line courses and examinations compared to the traditional face-to-face courses. They have also showed that students benefited most from computer-based courses and assessments that offer advantages over traditional methods [4], [10], [17].

Previous studies have also indicated that web-based learning environments including support systems for course tests and assessments are considered to have a high degree of necessity and will lead to better student performances by improving general knowledge and correcting specific details [1], [7], [8], [10].

Others have also demonstrated the advantages of computer assisted assessment modules (standard computing power, low time to complete) and have acknowledged the need of measuring and improving additional aspects of the programs such as non-standard behavior, exceptions, plagiarism detection) [18]. Also, it has been demonstrated that choosing to build a Web application will bring certain advantages over classic desktop applications [22].

Further analysis were also conducted in order to measure the system "effectiveness", "performance", "responsiveness" and provided "help from instructors", in order to improve the quality of these systems [4].

Several studies have been conducted in order to define the best assessment methods based on what is intended to measure – knowledge, decision making, practice performance, skills and tasks [5], [23]. They indicate that one of the main issues encountered in the assessment process consists in the incapacity of an appropriate management of the time assigned for assessment and maintaining the objectivity of the evaluation. Learning of student can be assessed by diverse types of questions (objective / subjective) and examination formats (easy, single choice, multiple choice, short answer and association questions) [3], [5].

Some authors have also proposed, in order to allow a meaningful computer-based analysis, the "intermediate constraint" questions that fall between the fully constrained responses (i.e single/multiple choice) and fully constructed responses (i.e. the traditional essay) [23].

Beside the advantages already mentioned, the computer-based automation of these tests enables a wider diversity of questionnaires and of question content, manages the process of scoring and performance reporting, allows randomizing of questionnaires and questions, and offers a real time feedback mechanism. [6], [20].

The selection of question types should be based on the types of outcomes the teacher is trying to assess and should take into consideration both pros and cons of each question type [9], [11], [25].

Choosing open source versus proprietary software and technologies like MySql database, Java platform and jBoss application server can bring all the benefits of using the latest IT technologies and open platforms with minimal costs [13], [14], [19].

Studies have acknowledged that from the large variety of open source technologies available to implement such applications, Java and MySql are proven to be adequate for such software tools [4], [8].

Various e-learning standards are available and define the compatibility, interoperability, reusability, shareability and efficiency of learning systems. Approaches were proposed to improve these aspects and develop assessment tests [15].

Of great concern is also the compatibility of the assessment content to the standards. While more than half of the assessment documents on the market are created using non-standard formats (especially Microsoft Word), the use of XML format is recommended [15].

II. Material and Method

Several modern solutions and technologies are available in the fields of online assessment and e-learning. They address some of the described assessment challenges but often the access to such applications is prohibited due to the big associated costs.

The aim of our study was to implement a modern solution that will address the issues described above with a low cost and in the same time to make it available and easy accessible to all categories involved in the educational process of the Faculty of Medicine from the "Transilvania" University of Brasov: teachers, undergraduate and postgraduate students, resident doctors. The application is trying to address all these mentioned issues.

Our goal was to build a Web-based application that is addressed to three categories of users: administrators, teachers (examiners) and regular users (examined pupils). It offers the possibility of a computer based assessment for a large variety of question models, so that a large area of knowledge can be assessed in a limited timeframe, for a big number of students. It also uses all possible types of question formats that are appropriate in the process of knowledge assessment in the field of Microbiology, but can be also used in several other areas related or not to medicine.

When choosing the software and technology we had to take advantage of the new IT technologies and open platforms with minimal costs. Such, we have chosen to use the Java J2EE platform due to the following advantages:

- open source and free;
- platform independent;
- provides security features;
- provides support for web services;
- performance and efficiency;

The chosen database was mySql due to the following reasons:

- open source and free;
- performance (reduced disk space, CPU and memory).

The Java-based Web application was deployed on a jBoss application server, a featured, robust and performing low cost alternative to the other proprietary application servers.

The system is modular in order to allow the examiners to store question banks, the students to register for self-test and online examinations. It is a multi-task, multi-user application allowing a simultaneous usage for the assessment processes and self-testing by multiple users of different disciplines.

Since computer based assessment can be used at several points in a course depending on the purpose of the assessment, the application was developed so that it can be used in the different stages of the learning process for:

- self testing (students can use the application for their own assessment during the course, to identify learning needs);
- formative assessment (the application should allow to measure student performance and teachers course effectiveness) ;

- final assessment (students have to pass the examination)

The innovative aspect of our application consists in a module that will maintain the objectivity of the assessment process by preserving the same set of questions in the examination form for all the tested students. This feature is provided by creating an examination template, responsible for arranging the questions in a randomized manner and in the same time for switching the order of the response options being presented to the user. The application allows also the generation of a pre-examination test that can be used for self-testing. The final goal of the application is to use the same questionnaire for each student even if they look to be customized.

The selection of question types and number contained in the assessment form should be done by the teacher using an intuitive user interface, based on the types of outcomes he is trying to assess.

The results of the assessments should be stored in the database in order to be used later on for the follow up of performance and further analysis. The data will also be used for gathering meaningful information in order to improve the learning process and reach a higher level of performance.

The implementation of the program during the university study year will allow the students to self-test their knowledge in order to improve and optimize the learning process, track down the understanding and learning issues and for acquiring of abilities.

The application was developed so that it can be easily extended in the future with new types of questions and modules.

III. IMPLEMENTATION ASPECTS

A. Requirements

For designing the Web application we had to define the requirements. These were:

- The application should be used by users of different disciplines;
- Should be a multi-user application, allowing the assessment of multiple users in the same time.
- Should allow examiners and users registration by defining security constrains based on user roles;
- Should allow the storage of data collections and high quality images;
- Should have an intuitive, easy to use, user interface;
- Should provide a module for the management of the assessment process (allowing the selection for response time per question and/or complete test, scoring mode, result presentation);
- Should allow the examiners to store different types of questions. These are:
  - simple questions (answer can be yes or no);
  - single choice questions (only one correct answer from the list)
  - multiple choice questions (one or more correct answer from the list)
  - associations (associations between items contained in two lists)
  - short answer questions (definition of basic terms or processes)
  - image representations
- Should allow CRUD (create, read, update, delete) operations for the stored data;
- Should contain a module for generating the assessment forms. Questions should be generated in such way that it ensures the objectivity and complexity of the assessment process.
- Should be easy accessible through both internet and university LAN.
- Should be expandable in the future;

B. Design

The database schema is presented in Figure 1.

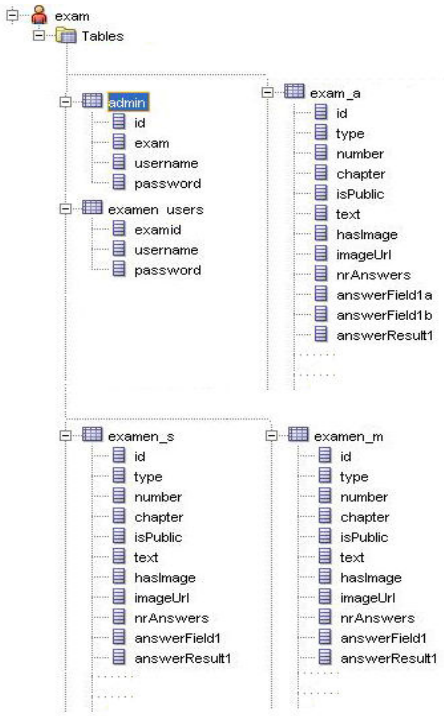


Fig. 1 - database schema

In designing the application we should take into account the needs of both examiners and examined users, as presented below:

- identifying the main questions that are specific to each section of the exam;
- determining the questions that are required to be answered to, allowing the module to select randomly the other questions up to the total number selected for the questionnaire;
- allowing alerts that will help the user to easily determine the questions he has accidentally skipped;
- providing help tools for time management;
- allow temporary savings and easy back and forth

navigation between questions;
- allow immediate presentation of test result if option is activated by the examiner.

The proposed implementation is a client-server Web application written in Java programming language as shown in Figure 2 below.

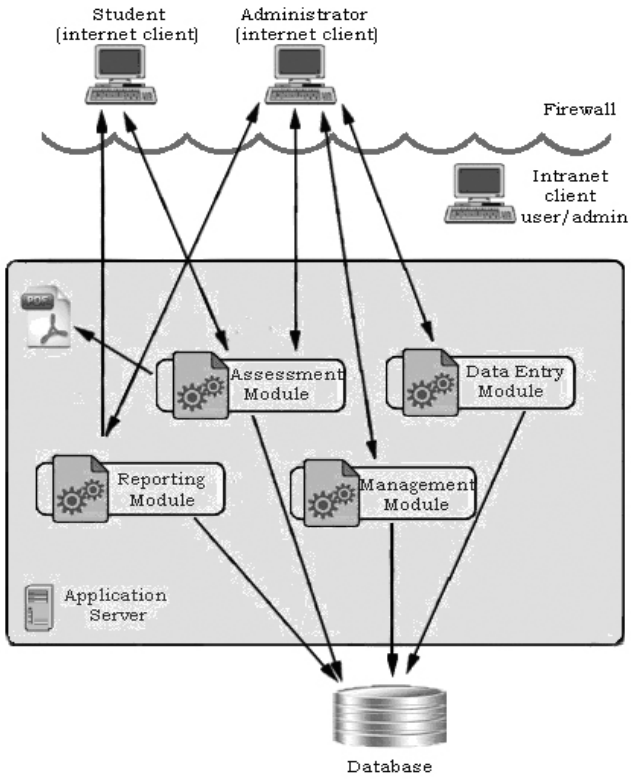


Fig. 2 - application modules

In the development process we have used the following frameworks and technologies:
- Jakarta Struts (including Tiles) open-source framework, providing a Model-View-Controller (MVC) architecture;
- JSP (Java Server Pages) and custom tag libraries used to build the user interface;
- Hibernate framework, used to map the object-oriented domain model to the mySql relational database;
- XML (eXtensible Markup Language), used for the data layer of our application;
- XSLT (Extensible Stylesheet Language Transformations) to generate PDF reports, assessment results and printable assessment forms.

Next we will describe the main design concepts, facilities and advantages offered by our application.

C. Data storage process

Each teacher will be granted by the administrator with rights to control all the aspects of his module. He is considered to be the administrator of his discipline.

The data entry (create) process for each discipline is performed by the examiner. He has the option to store in the database any of the six types of questions mentioned earlier.

A screenshot of the user interface used in the data entry process is presented in Figure3

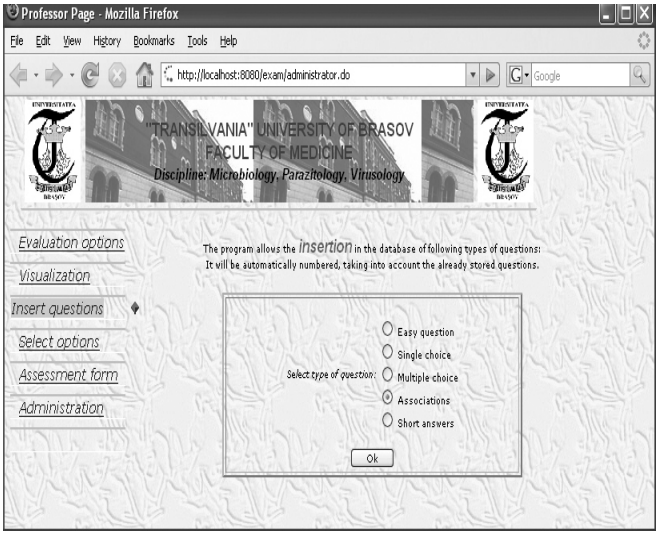


Fig. 3 - user interface: data storage

Examiners are also allowed to read (preview), update and delete the already stored entries.

A screenshot of the user interface used in the update process is presented in Figure4. As shown in this figure, the examiner can either change a specific response or add more response options to the query.

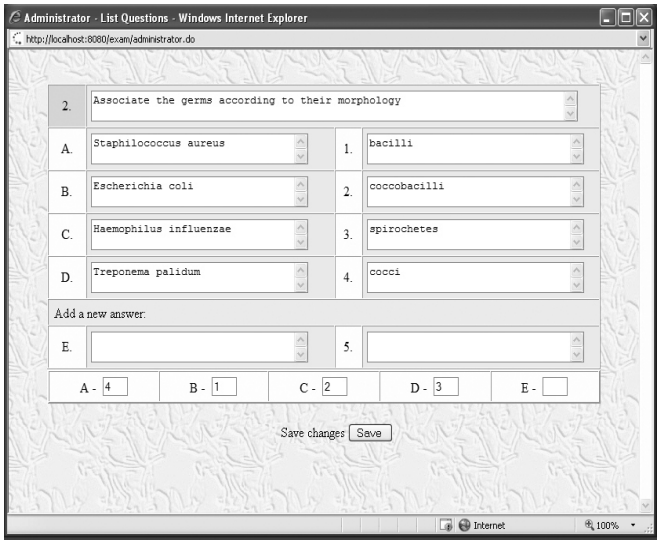


Fig. 4 - user interface: update query

D. Building the assessment template

Another module of our application offers the options for managing the template creation process.

The system flow of operations to build the template used for assessment is presented in figure 5.

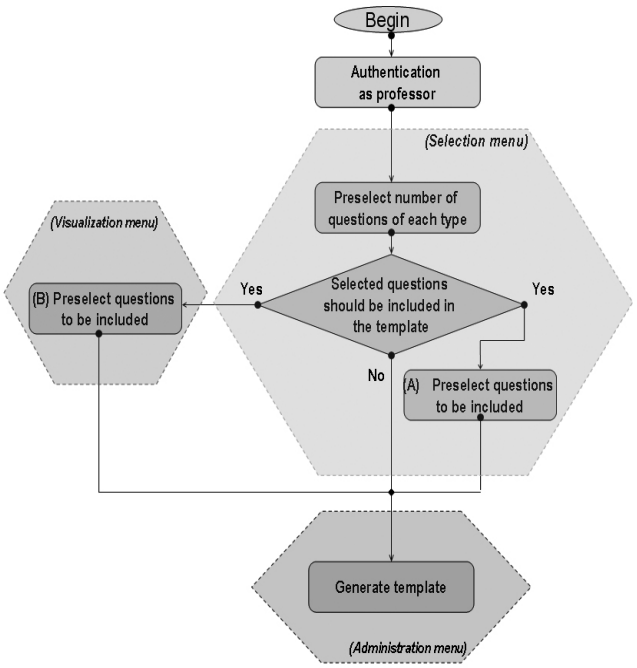


Fig. 5 – building the assessment template

In order to construct the assessment template, professors will have to choose the number of questions of each type to be included in the template. They can decide if some of the questions stored in the database will be included in the template. This option can be performed either from the selection menu (clicking on the question number to be added) or from the visualization menu. The advantage of using the latter option is that the examiner will have the question displayed in front of him, the selection being done as simple as a mouse click.

Figure 6 presents the UI available to the professor for selecting the number of questions to be included in the assessment template.

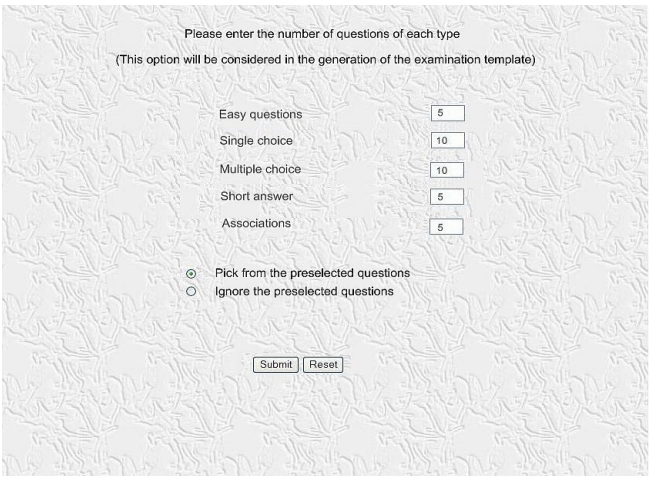


Fig. 6 - user interface: selection options

Based on the number of questions of each type that were selected, the template generation module will be responsible to pick the teachers selections and randomly select the other questions, up to the total number of questions that were selected.

Once the template is generated, it will be stored in form of an XML file and used later in generating the assessment forms of all the students taking the examination. At any time, the template can be previewed, transformed into a PDF document and printed. The response keys are also listed at the end of this generated document.

E. Delete and update operations

As shown in the requirements section, the option of deleting and updating stored queries is available. This can be done from visualization menu. The professor can choose to select questions based on type and will have the option to select/delete/update each of the presented queries. The necessity of having a new 'copy' option has resulted after the first use of the application and will be added in the future.

F. Assessment management process

The system flow of operations used for managing the assessment process is presented in figure 7.

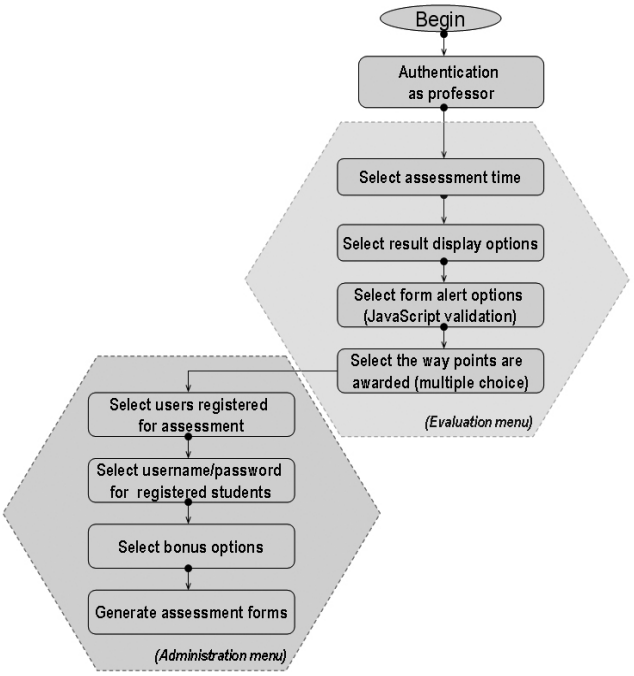


Fig. 7 – assessment management process

The examiner will decide the way the results are calculated and displayed. This is very important since multiple choice questions and associations can be rated in different ways. The module offers also some help tools for time management and validation that can be made available to the users based on teacher's selection. This include the ability to select a convenient time for taking the test, save the partial results and continue after a short brake, opportunities to reset some answers, information about the tasks to perform based on question type and opportunity for feedback.

Professors are also responsible to provide the list of users registered for the examination and select usernames and passwords for each of them. If some practical examinations are to be included in the final evaluation grade, the number of points for each student can be stored in order to be taken into account, when displaying the final assessment result.

Once this last step is completed, the application generates (as simple as a button click) the questionnaires of each user.

The innovative aspect of Web application consists in a special dedicated module responsible for arranging the question included in the template in randomized manner, for the order of questions within a questionnaire and answers within a question. Such, all tested users will have in their assessment form the same set of questions and answers, even if, at a first view, they appear to be different, so that the diversity and objectivity of the examination is granted.

G. *Assessment form*

Figure 5 below shows a section from the Web-based examination form.

2.	Is gonorrhoea a venereal disease?
○	Yes.
○	No.

3.	Asociate the diseases with their ethiological agents:		
A.	Syphilis	1.	S. typhi
B.	Typhoid fever	2.	R. prowazekii
C.	Disenteria	3.	T. pallidum
D.	Epidemic typhus	4.	S. sonnei
A - ☐	B - ☐	C - ☐	D - ☐

4.	Select the facultative components of bacterial cell:
☐	Nuclear material
☐	Capsule
☐	Cell wall
☐	Spores

5.	The elective stain for the detection of tuberculosis agents is:
☐	Gram
☐	Ziehl-Nielsen
☐	Giemsa
☐	Del Vecchio

Fig. 8 - assessment form

The main advantage of this questionnaire, compared to other examination forms consists in the objectivity of the examination (same questions and answers in the form even if they look to be different because of the random arrangement) and selectivity since the most important questions have been selected to be included in the form. The simple and user friendly user interface is also an important feature.

The assessment form will contain also some JavaScript validation functions, generated based on the examiners selections in the management process. These consist in validating student selections like selecting the same number twice for an association question, choosing multiple answers for single choice questions (usually used for self assessments), alerting that a question was skipped (no selection) and other.

H. *Display and reports*

The assessment template and all assessment forms are saved as XML documents (see figure 9). This is transformed in html by the display module and shown in the user interface. Another important aspect of having this in xml format is that we could, in the future, extend the possibility of allowing the students to take the examination from any client application other than web browsers, like PDA's or mobile devices.

```
- <root>
  - <questionForm questions="20">
    - <question id="1" type="S" nr="21">
        . . .
      </question>
    - <question id="2" type="S" nr="16">
        <qText>Select the characteristics of Pseudomonas aeruginosa:</qText>
        <answer nr="a">gram negative bacilli</answer>
        <answer nr="b">gold-yellow pigment</answer>
        <answer nr="c">fetid smell</answer>
        <answer nr="d">anaerobe germ</answer>
      </question>
        . . .
    - <question id="4" type="M" nr="6">
        <qText>The penicillin antibiotics are active on:</qText>
        <answer nr="a">Gram negative cocci</answer>
        <answer nr="b">Gram positive cocci</answer>
        <answer nr="c">Gram positive bacilli</answer>
        <answer nr="d">Gram negative bacilli</answer>
      </question>
        . . .
    - <response id="7" type="M" nr="4">
        <answer>a</answer>
        <answer>c</answer>
        <answer>d</answer>
      </response>
    - <response id="8" type="A" nr="3">
        <answer>a - 4</answer>
        <answer>b - 3</answer>
        <answer>c - 2</answer>
        <answer>d - 1</answer>
      </response>
        . . .
    </questionForm>
  </root>
```

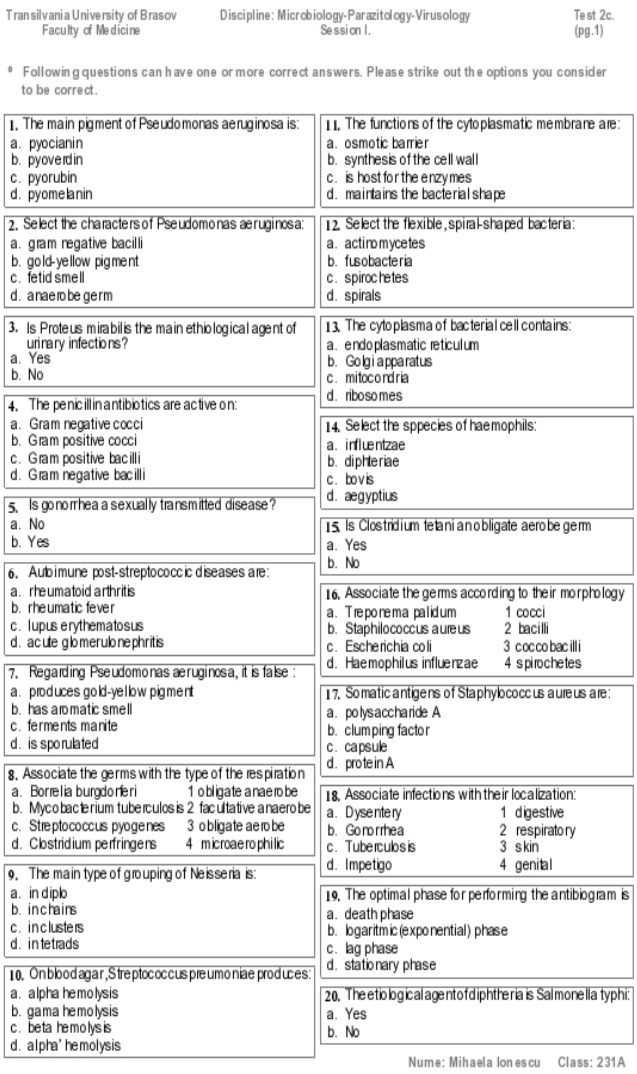
Fig. 9 – XML assessment document

Once the assessment process was completed, the display module of our application has the ability to show the examination form, answers and score results, to both examiner and student. This can be done either as a Web form or generate it as a PDF document (see figures 10 and 11). This feature is very useful for students in case of self evaluation tests and for teachers, to track the progress and review how students have performed.

Correct question answers:	Student answers:
1. a,	1. a - Score: 0,5 p
2. a,	2. b - Score: 0 p
3. b,	3. b - Score: 0,5 p
4. a, b, c,	4. a, b - Score: 0,375 p
5. b,	5. b - Score: 0,5 p
6. b, d,	6. b, c, d - Score: 0,375 p
7. a, c, d,	7. a, c, d - Score: 0,5p
8. a - 4, b - 3, c - 2, d - 1,	8. a - 4, b - 3, c - 1, d - 2 - Score: 0,25p
9. a,	9. a - Score: 0,5p
10. a,	10. a - Score: 0,5p
11. a, b, c,	11. a, b - Score: 0,375p
12. c,	12. c - Score: 0,5p
13. d,	13. d - Score: 0,5p
14. a, d,	14. a, d - Score: 0,5p
15. b,	15. a - Score: 0 p
16. a - 4, b - 1, c - 2, d - 3,	16. a - 4, b - 1, c - 2, d - 3 - Score: 0,5p
17. a, b, d,	17. a, b, d - Score: 0,5p
18. a - 1, b - 4, c - 2, d - 3,	18. a - 1, b - 4, c - 2, d - 3 - Score: 0,5p
19. b,	19. c - Score: 0 p
20. b,	20. b - Score: 0,5p
	Total: 7,875 p
	Starting points: 1 p
	Final result: 9 p

Fig. 10 - assessment results

The PDF document can be also generated before the assessment process has been started, so that the assessment can be done either online or offline, using a paper form. This feature is useful especially for making some comparative studies for student response and results in online versus offline assessments or for teachers that want to perform an offline assessment.



Transilvania University of Brasov — Discipline: Microbiology-Parazitology-Virusology — Test 2c.
Faculty of Medicine — Session I. — (pg.1)

* Following questions can have one or more correct answers. Please strike out the options you consider to be correct.

1. The main pigment of Pseudomonas aeruginosa is:
a. pyocianin
b. pyoverdin
c. pyorubin
d. pyomelanin

2. Select the characters of Pseudomonas aeruginosa:
a. gram negative bacilli
b. gold-yellow pigment
c. fetid smell
d. anaerobe germ

3. Is Proteus mirabilis the main ethiological agent of urinary infections?
a. Yes
b. No

4. The penicillin antibiotics are active on:
a. Gram negative cocci
b. Gram positive cocci
c. Gram positive bacilli
d. Gram negative bacilli

5. Is gonorrhea a sexually transmitted disease?
a. No
b. Yes

6. Autoimune post-streptococcic diseases are:
a. rheumatoid arthritis
b. rheumatic fever
c. lupus erythematosus
d. acute glomerulonephritis

7. Regarding Pseudomonas aeruginosa, it is false :
a. produces gold-yellow pigment
b. has aromatic smell
c. ferments manite
d. is sporulated

8. Associate the germs with the type of the respiration
a. Borrelia burgdorferi — 1 obligate anaerobe
b. Mycobacterium tuberculosis — 2 facultative anaerobe
c. Streptococcus pyogenes — 3 obligate aerobe
d. Clostridium perfringens — 4 microaerophilic

9. The main type of grouping of Neisseria is:
a. in diplo
b. in chains
c. in clusters
d. in tetrads

10. On blood agar, Streptococcus preumoniae produces:
a. alpha hemolysis
b. gama hemolysis
c. beta hemolysis
d. alpha' hemolysis

11. The functions of the cytoplasmatic membrane are:
a. osmotic barrier
b. synthesis of the cell wall
c. is host for the enzymes
d. maintains the bacterial shape

12. Select the flexible, spiral-shaped bacteria:
a. actinomycetes
b. fusobacteria
c. spirochetes
d. spirals

13. The cytoplasma of bacterial cell contains:
a. endoplasmatic reticulum
b. Golgi apparatus
c. mitocondria
d. ribosomes

14. Select the sppecies of haemophils:
a. influentzae
b. diphteriae
c. bovis
d. aegyptius

15. Is Clostridium tetani an obligate aerobe germ
a. Yes
b. No

16. Associate the germs according to their morphology
a. Treponema palidum — 1 cocci
b. Staphilococcus aureus — 2 bacilli
c. Escherichia coli — 3 coccobacilli
d. Haemophilus influenzae — 4 spirochetes

17. Somatic antigens of Staphylococcus aureus are:
a. polysaccharide A
b. clumping factor
c. capsule
d. protein A

18. Associate infections with their localization:
a. Dysentery — 1 digestive
b. Gonorrhea — 2 respiratory
c. Tuberculosis — 3 skin
d. Impetigo — 4 genital

19. The optimal phase for performing the antibiogram is
a. death phase
b. logaritmic (exponential) phase
c. lag phase
d. stationary phase

20. The etiological agent of diphtheria is Salmonella typhi:
a. Yes
b. No

Nume: Mihaela Ionescu Class: 231A

Fig. 11 - assessment form

IV. RESULTS AND DISCUSSIONS

The described methodology was experimentally tested in the domain of bacteriology, virusology, parasitology in the "Department of Fundamental and Prophylactic Disciplines" from the Faculty of Medicine of the "Transilvania" University of Brasov, Romania.

The use of this application in the examination sessions allows the evaluation of the acquired level of knowledge as well as of some abilities regarding the reaction speed and use of information, synthesis capacity and links between theory and clinical practice.

In the domain of Microbiology – Virusology – Parasitology, the program enables the achievement and assay of both theoretical and practical knowledge, by offering the possibility of understanding and refining the concepts of microbial and parasitical morphology through the use of image representations of microscopic preparates.

Putting in practice this methodology has leaded to a larger diversity of tests and of their content, significant decrease of the time spent for the examination and communication of results and in better results in the process of evaluation and scoring.

The obtained assessment results have demonstrated the need of the application and lead to the necessity of extending it by:

- adding more types of questions (like multimedia-support questions)
- allowing adaptive testing, in which questions can be picked at the level of expertise of each candidate (more easy or increasing in difficulty based on student answers).
- Adapt the user interface so that menus and alerts should use property files. Such, the user interface can be displayed in several user languages based on the computer locale settings.

V. CONCLUSION

Web-based assessment tools are in our days complex and rapidly emerging, involving many considerations like interactivity, performance and feedback, offering great potential for improving the assessment and self-testing of students and residents in medicine and many advantages over traditional assessment methods.

Computer based assessment in medicine has become much more important in or days as information technology has become a key factor in the educational process.

Our Web-based application has been tested with success in the field of Microbiology and provides a set of advantages over other assessment tools. These are:

- preserves the same set of questions in the examination form for all the tested users by arranging the questions and answers in randomized manner, maintaining this way the objectivity of the assessment process;
- wider diversity of questionnaires and of question content, easy managed by a friendly user interface;
- ability to manage the process of scoring and performance reporting;
- low cost solution benefiting from the new IT open source technologies;
- easy to extend in any educational field related, but not limited only to medical disciplines;
- easy to adapt to any client application like PDA's and mobile devices due to the xml format used;
- decrease of the overall examination time being a multi-task, multi-user application;
- increase in results accuracy due to the scoring module;
- allows self-testing during the university study year and so improves and refines the studied concepts;

- offers several help tools for time management and validation;
- offers feedback options;
- ability to follow up students performance and perform further analysis.

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