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A Formative Assessment Tool for Effective Feedback

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Abstract**—**In this study we present our developed formative assessment tool for students' assignments. The tool enables lecturers to define assignments for the course and assign each problem in each assignment a list of criteria and weights by which the students' work is evaluated. During assessment, the lecturers feed the scores for each criterion with justifications. When the scores of the current assignment are completely fed in, the tool automatically generates reports for both students and lecturers. The students receive a report by email including detailed description of their assessed work, their relative score and their progress across the criteria along the course timeline. This information is presented via charts generated automatically by the tool based on the scores fed in. The lecturers receive a report that includes summative (e.g., averages, standard deviations) and detailed (e.g., histogram) data of the current assignment. This information enables the lecturers to follow the class achievements and adjust the learning process accordingly. The tool was examined on two pilot groups of college students that study a course in (1) Object-Oriented Programming (2) Plane Geometry. Results reveal that most of the students were satisfied with the assessment process and the reports produced by the tool. The lecturers who used the tool were also satisfied with the reports and their contribution to the learning process.

Keywords**—**Computer-based formative assessment tool, science education.

I. Introduction

HOMEWORK assignments are often given to assist students with the assimilation of theoretical knowledge and in some domains the development of practical skills. To make the learning process more effective, a significant feedback should be provided to the students on their handed assignments. Formative assessment is considered to be useful for this purpose especially for domains in which practical skills should be developed and shaped. For instance, when studying mathematics or computer programming one needs to be engaged in the solving of many problems in order to develop problem solving skills. Moreover, in certain domains, there are guidelines regarding the quality of the provided solution. In addition to their correctness, solutions to problems in plane geometry requires one to provide a clear sketch, justifications for each claim, accurate references to known theorems and coherent arrangement of claims.

Solutions to computer programming problems should be modular, efficient, clear, validated and accurate [5]. Students who studied courses in such knowledge domains must shape their ability to handle problems in all aspects involved.

Formative assessment can contribute significantly to the student learning process. It helps students become more aware of any gaps that exist between their desired and their current knowledge and encourages them to narrow these gaps during the semester before the final exam takes place. Meaningful learning process requires a feedback that is comprehensive, detailed, clear, continual, individual and summative. The students should grasp their learning situation by the ability to identify their strengths and weaknesses. By receiving proper feedback both on correct and faulty solutions the students can adjust their efforts to gain overall improvement. By tracking their achievements along the course timeline the students can better diagnose their progress and understand their learning status. Teachers on the other hand can track the performances of individual students in order to guide and assist them to improve their achievements, and can follow the class understanding using the summative data and rehearse issues that students struggle with and solve problems that many students failed to address.

An international study of computer science academics conducted by Carter et al. [6] reveals that 74% of respondents assess programming assignments submitted by their students merely for their correctness. Most educators examine and grade the students' assignment manually, but many prefer automatic tools to ease the efforts required for this task in large courses. The most common technique to test the correctness of the provided solution is to execute it on predefined data and inspect the output compared with the expected results. There are many such automatic tools [9] in use (e.g., Online Judge [7], CourseMarker [11], BOSS [15], Assyst [16], HoGG [20]). Ala-Mutka [1] describes the methods and techniques used by automated assessment tools and shows how they are generally used. In addition to correctness, some assessment tools analyze program efficiency, coding style and the existence of inline documentation. The use of automatic testing process forces students to be very accurate in order to gain maximal score. However, automatic tools cannot examine whether a variable name is meaningful or if the program constituents were properly designed. It focuses mainly on the correctness of the solutions and neglects other important properties. Moreover, the students conclude that the only factor that counts is the correctness, and hence focus their attention achieving this goal at the expense of other properties. Howles [13] discovered from a local student survey that only 5% of the responding students invest time and efforts to design their work before

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coding and only 39% test their code statically. Majority of the students tested their code dynamically (e.g., unit testing) only sometimes or never.

Mathematical lecturers rarely have opportunities to engage in assessment design [24]. According to Aksu [2], lecturers have negative attitudes towards the idea of using alternative assessment techniques such as formative, peer or self-assessment because of their traditional thoughts and fixations. Implementing formative assessment effectively requires lecturers to reconceptualize their role as teachers, the roles of students and their interactions with students [4]. Moreover, in most cases students are not a priory informed on the criteria by which their work is going to be assessed that could impair their learning effectiveness. The lecturers' avoidance from engaging in innovative assessment tools originates in their complex nature. Since the assessment process consists of several phases that have to be planned and designed by the lecturer, we believe that providing lecturers with a structured assessment tool that will serve as scaffold for the various stages of the assessment process may encourage them to incorporate formative assessment technique in their practice.

In this paper we suggest a novice assessment tool that can support the learning process in science courses, supporting and enhancing the various stages of the assessment process including designing the list of tasks for the students; setting criteria set for each task; assessing and commenting on each problem across the various criteria selected and receiving individual and summative reports regarding the class progress along the course timeline. The students can benefit from the suggested tool by receiving the criteria a priory; receiving detailed assessment of their learning progress; explore their relative achievements; and track their progress across the various assessment criteria. To address both the teachers' need for a constructive assessment tool and students' need for meaningful feedback on their assignments, the aim of this study is to examine both the teacher's and the students' impressions of the suggested assessment tool. For that matter, the tool is tested nowadays on two pilot groups of students' college studying (1) 'object-oriented programming'; (2) 'Plane geometry'. In both courses the students are required to hand assignments that were assessed via the developed tool. In this paper, we present preliminary results obtained from both pilot groups and their teaching staff.

II. Theoretical Background

In this section we present a brief theoretical background regarding assessment in higher education and formative assessment.

A. Assessment in Higher Education

The relationship between assessment practices and the overall quality of teaching and learning is often underestimated, yet assessment requirements and the clarity of assessment criteria and standards, significantly influence the effectiveness of student learning [10]. Carefully designed assessment guidelines directly influence the ways in which students approach their studies, and therefore contribute indirectly, but effectively, to the quality of their learning. For most students, assessment requirements literally reflect the curriculum. Assessment is therefore a powerful strategic tool for educators to clarify which kinds of learning will be rewarded and to guide students into effective approaches to study.

Achieving a higher level of students' self-directedness in learning, and enhancing students' development of learning autonomy [18], are among the motivations for having student-based assessments. According to James et al. [14], the examination of student learning supports three objectives for quality in student assessment in higher education: (1) assessment that guides and supports effective approaches to learning; (2) assessment that validly and reliably measures expected learning outcomes, in particular the higher-order learning that characterizes higher education; (3) assessment and grading that defines and protects academic standards.

Assessment is treated by educators and students as an integral and important component of the teaching and learning process rather than as a final add-on [18]. The powerful motivating effect of assessment requirements on students is understood and assessment tasks are designed to encourage valued study habits. There is a clear connection between expected learning outcomes, what is taught and learned, and the knowledge and skills assessed. Assessment tasks evaluate student's abilities to analyze and synthesize new information and concepts rather than simply remember information previously presented [23]. A variety of assessment methods is employed so that the limitation of any one particular technique is minimized. Assessment tasks are designed to appraise relevant generic skills as well as subject-specific knowledge and expertise. There is a steady development in the complexity and demands of assessment requirements in more advanced courses. Assessment tasks are weighted to balance developmental (‘formative’) and judgmental (‘summative’) evaluative functions. Grades are calculated and reported on the basis of clearly articulated learning outcomes and criteria for levels of achievement. Students receive descriptive and diagnostic feedback, as well as numerical grades.

Students study more effectively when they know what is expected of them. They appreciate and expect transparency in the way their knowledge acquisition will be judged. They wish to see a clear relationship between lectures, tutorials, practical classes, and subject resources, and the knowledge they are expected to demonstrate. They also wish to understand how grades are determined and expect feedback that not only explains the grade received, but that rewards achievement appropriately. In addition they look for suggestions that enable them to improve themselves as learners.

Capturing the full educational benefits of a well-designed assessment requires that many of the conventional assumptions about assessment in higher education be reconsidered. For the academic staff, assessment is often a final consideration in the planning of their curricula. This is not to imply that staff underestimates or undervalues the role or importance of assessment, but assessment is often considered only after other curricular decisions have been made. The primary concerns of academic staff are often with designing learning outcomes and planning teaching and learning activities that will produce these outcomes. In contrast, students often work ‘backwards’ through the curriculum, focusing first and foremost on how they will be assessed and what they will be required to demonstrate they have learned [18].

Assessment tasks are weighted to balance developmental (‘formative’) and judgmental (‘summative’) evaluative functions. An elaboration on formative assessment - the assessment method which we employed in the present study - follows.

B. Formative Assessment

Formative assessment (FA) is considers to be one of the effective assessment techniques since it helps students become more aware of any gaps that exist between their desired and their current knowledge. FA concerns with a range of formal and informal assessment procedures employed by teachers during the learning process in order to modify teaching and learning activities to improve student attainment [8]. FA involves the setting of learning goals and the assessment of students' fulfillment of these goals. Effective feedback on students' assignments provides specific comments about errors and specific suggestions for improvement and encourages students to focus their attention thoughtfully on the task rather than on simply getting the right answer [3].

One of the assessment methods used in evaluating teaching and learning outcomes is Formative Assessment (FA). One of its main characteristic is to enhance the evaluation processes through continual assessment. An evaluation of one stage, for example, takes into consideration the previous stage and as a result improves its performance. FA assignments provide both teachers and students with feedback which might prompt revisions in the way teachers teach and students learn. FA necessitates constant follow-up and as a result the teacher is regularly informed regarding the students’ progress or difficulties and can adjust his/her teaching accordingly. Through FA the teacher can know whether what has been taught has been learned. It allows teachers to reflect on their practice and to make incremental changes that improve that practice in powerful ways. William and Thompson [26] suggest five strategies for establishing effective FA: (1) understanding, cooperation, and perception of the learning aims and setting criteria for success with students. Wiggins and McTighe [25] support a two-step process in which the learning aims are clarified and then clear criteria for success are set (considered 'understanding'); (2) using effective class discussions, tasks, and activities which reflect the course of reaching the learning aims; (3) providing the students with feedback which can promote the learning process. This feedback should include verbal recommendations [21], or encourage the students to reflect on their own learning processes [12], or discuss ideas with classmates; (4) encouraging the students to take responsibility for their learning processes; (5) cooperative work. Slavin et al. [22] showed that students mutually operating as learning resources benefited more when it came to understanding the learned topics. However they said that two conditions must be fulfilled: the learning environment must provide the learners with group aims, and each learner needs to have a sense of personal accountability toward his group. In fact, the assessment method which we employed in the present study took into account these five strategies. We will broadly refer to them later.

Being aware of the advantages of formative assessment, we developed a computer-based tool to enhance the assessment process for both teachers and students. Teachers are able to plan assignments and criteria according to which their students' assignments will be assessed, feed in their assessments in a standard way that relates to each criterion explicitly, and track students' achievements through individual and summative reports. Students are notified in advance on the criteria that will be used to assess their assignments and receive accumulated feedback represented visually and literally of all the assignments they hand along the course.

III. The Study

In this section we provide a detailed description of our suggested assessment tool and its use followed by a description of the pilot study done to evaluate the tool.

A. The Assessment Tool

The architecture of the suggested tool is based on Microsoft Excel, where its entire logic is developed, using Visual Basic for Application (VBA) to provide all its functionality. This environment was chosen since it is part of the Microsoft office suit and is available everywhere with no special installation needed. The tool was designed and constructed based on our educational perceptions. We believe that assessment process should meet several conditions: (1) the students should be notified on the criteria list by which their assignments will be evaluated in advance. This way they can adjust their learning accordingly [19]; (2) the evaluation process should reflect the students' progress across each assessment criterion along the course timeline, so that they can focus their efforts in issues they encounter difficulties; (3) the evaluation process should demonstrate the student's relative position with comparison to the whole class achievements. This information might help the student to better grasp his learning situation; (4) evaluation via the tool encourage the teaching staff to assess the students' assignments systematically and efficiently. The standard format of the assessment process avoids differences between the provided assessments especially when more than one assessor is involved; (5) the provided assessment should be clear and concise. Therefore, the tool should provide both textual and visual feedback of each assessment criterion.

Fig. 1 presents the menu of the assessment tool that enables the teacher to select the desired operation.

In what follows we present a sequence of steps demonstrating the tool's operations.

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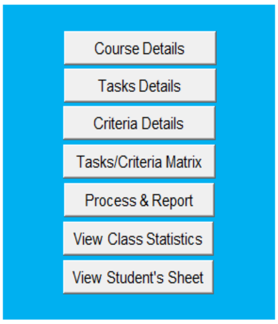

Fig. 1 Menu

Step 1: Setting the course details including the course staff (Title, teacher_name, e-mail address) and the students' details (student_no.,student_name, e-mail address). Fig. 2 presents an example of the course sheet.

Students			
Id	**Last name**	**First name**	**Email**
111	Lovelace	Ada (Byron)	ada@gmail.com
222	Babbage	Charles	charles@gmail.com
Course Staff			
Title	**Last name**	**First name**	**Email**
Dr.	Jackyll	Henry	henry@gmail.com
Mr.	Hyde	Edward	edward@gmail.com
Miss	Piggy	Lee	piggy@gmail.com

Fig. 2 Course details

Step 2: Setting the tasks details. The teaching staff has to enter the list of the tasks planned for this course and their relative weight, and the number of problem in each task. Fig. 3 presents the tasks planned for the pilot group.

Task no.	Task desc	No. of Problems	Task weight(%)
1	intro to Java program, basic program syntax	3	10
2	algorithmics, conditions, loops	4	10
3	first class & object, simple meethods	4	10
4	constructors, advanced methods	5	15
5	class inheritance, polymorphism	4	20
6	abstract methods & classes, interface classes	4	20
7	Exceptions, files	3	15
	total		100

Fig. 3 Planned tasks

Step 3: Setting criteria list to be used for the assessment of the various tasks. It should be noted that not all the criteria have to be used in each task. Fig. 4 presents the criteria according to which the tasks of the pilot group were assessed.

Step 4: Setting the task/criteria matrix. The teacher assigns relative weights to criteria for each problem in each task. Fig. 5 presents the criteria and relative weights of the first task given to the pilot group.

Criteria	Description
Modularity	Code should be effectively organized into classes and classes are organized into class hierarchies addressing problem specifications. Each class represents a single concept and has all the necessary attributes and methods.
Method design	Each method should be relatively short and perform a single task or a small number of highly related tasks.
Code Readability	Code should include meaningfull names for classes, variables and methods. Layout should include indentation and wrapping of long lines. Inline documentation should be added.
Correct solution	The program does what it is expected to do according to the problem specifications. It runs smoothly without failures.
Code coverage	Test program should be associated including high percentage of code coverage

Fig. 4 Criteria set

Task 1						
Problem no.	Modularity	Method design	Code readability	Correct solution	Code coverage	**Total**
1	10	20	10	50		100
2	25	15	10	50		100
3	15	15	15	45	10	100
Task 2						
Problem no.	Modularity	Method design	Code readability	Correct solution	Code coverage	**Total**
1	30	10	10	30	10	100
2	25	10	20	40	5	100
3	25	15	10	40	10	100
4	10			90		100

Fig. 5 Relative weights to criteria

Step 5: Task assessment according to criteria – after examination of the students' tasks by the teaching staff, the scores are entered to the suitable sheet and justifications to each score is provided. Fig. 6 presents a partial assessment of one of the problems in a task given to the pilot group.

Step 6: Processing task data and generating reports for the students – after all scores and justifications for the problems of the current task are entered, the data are automatically processed and the tool generates reports for both students (personal report) and teaching staff (summative report). All the reports are sent automatically by mail, according to the personal details of the students and teaching staff (Fig. 2).

Student report: The report includes detailed assessment of the current task, literal and graphical description. Figs. 7 and 8 present the literal and the graphical assessment reports of one student from the pilot group. In addition, the report includes charts presenting the student's progress across the various tasks in each criterion and the student' relative position in class in each task. Figs. 9 and 10 present the progress and the relative position of one student from the pilot group.

Teaching staff report: The report includes summative assessment of the current task. Fig. 11 presents the averages and standard deviations of all tasks' scores (including the last one). Fig. 12 presents score distribution of the current task, in each criterion. Fig. 13 presents the average data within a graph showing the progress of the class as a whole from one task to the next.

Modularity	Comments
21	Class Dog should be extracted from class Animal.
Method design	**Comments**
12	Constructor of Anumal is too long. It should call set methods instead of initializing the attribute itself
Code readability	**Comments**
7	methods' parameters are not documneted. Methods' names must not start with a capital letter.
Correct solution	**Comments**
40	very good!
Code coverage	**Comments**
8	A test with a Cat is missing

Fig. 6 An assessment example

Averages

Task No.	Correct	Modularity	Readability	Coverage	Total
t1	76	67	45	35	66
t2	80	55	77	50	70
t3	84	72	85	58	79
t4	86	78	89	70	72
t5	80	85	95	82	83

STDs

Task No.	Correct	Modularity	Readability	Coverage	Total
t1	25	21	16	24	22
t2	24	22	21	16	20
t3	19	13	17	19	17
t4	18	15	9	14	15
t5	10	12	9	10	11

Fig. 7 Student's feedback on a problem

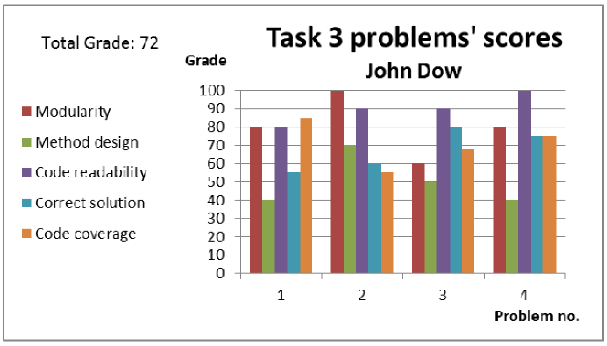

Fig. 8 Student's graphical report on a task

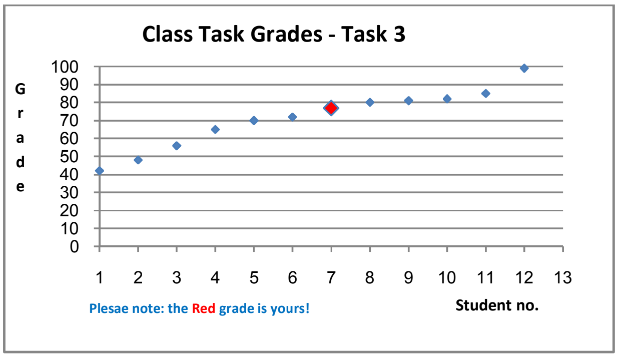

Fig. 9 Student's progress along selected criteria

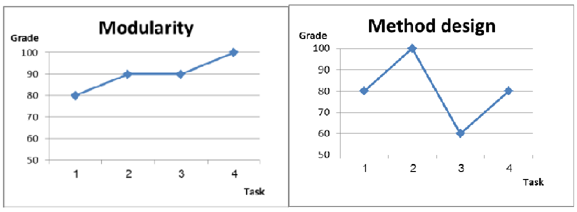

Fig. 10 Student's assessment summary

Task 3	Modularity	Method design	Code Readability	Correct solution	Code coverage
Problem 1	80	40	80	55	85

Comments

Modularity : Class Dog should implement Carnivore interface ; Method design: Animal.eat() is too long, Dog.eat() does not call super.eat(); Code Readability: quite good, but classes should start with a capital letter Code coverage: tests for Cat and Dog are missing]

Fig. 11 Summative report

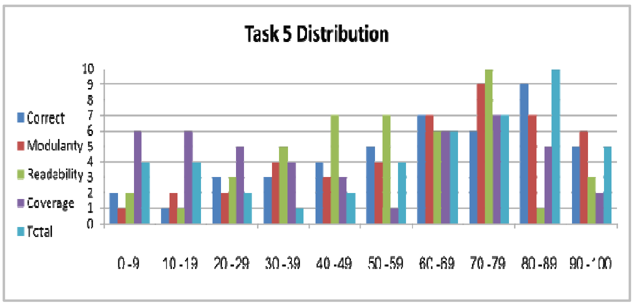

Fig. 12 Score distribution per criteria

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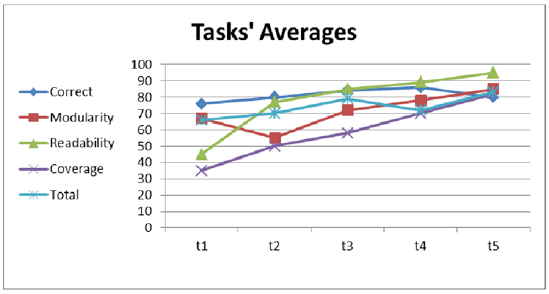

Fig. 13 Score Averages along the tasks

B. The Pilot

The assessment tool was examined on two pilot groups of college students learning in the following courses' Object-Oriented Programming' and 'Plane Geometry'. The teaching staff of the object oriented programming course included a lecturer and two teaching assistants and the plane geometry course had only a lecturer with no teaching assistants.

One pilot group included first year included first year 45 college students studying towards B.A. degree in management information systems. The second pilot group 26 students studying towards B.A. degree in mathematics education. We used the tool in both courses.

In the first course the students learn the principles and constituents of object oriented, namely classes, methods, class inheritance, polymorphism, method override, abstract methods, abstract classes, interface class, exception mechanism and graphical user interfaces. The main focus of the course was on using these principles to provide modular, clear and qualitative software solutions to given problems. The course lecturer and his teaching assistant planned seven homework assignments each aimed to practice different issues. The lecturer defined five criteria by which the students' work will be assessed and assign weights to these criteria for each problem in each task. The criteria list comprised of the following: correctness, modularity, method design, readability and code coverage (e.g., testing).

In the second course the students learn the issues related to plane geometry including triangles and their attributes, special triangles, congruent theorems and triangle similarity. During the course the student had to provide formal proofs to geometry problems addressing roles and meaning of mathematical proofs such as correctness, communication, systematization and so forth. The course lecturer planned four homework assignments each aimed to practice different issues. The lecturer defined five criteria by which the students' work will be assessed and assign weights to these criteria for each problem in each task. The criteria list comprised of the following: correctness, clear sketch, justification, accurate reference to known theorems and systematization.

In both courses the criteria and their assigned weights were published to the students in advance. The teaching staff used the tool to feed in scores and feedbacks and generated the reports which were distributed automatically to the students via email.

IV. Results and Discussion

In this section we provide an analysis of the teaching staff and students reflections on the assessment tool used during the course.

A. Teaching Staff Perception

Analysis of the responses of the teaching staff to the question "describe your experience with the assessment tool", revealed the following issues: The extent to which the lecturer is involved in his students' learning situation; Facilitating the process of setting criteria for the assessment process in advance; Receiving a detailed picture of the current learning situation of each and every student; working with the assessment tool.

1. Degree of Involvement in the Students' Learning Situation

"*I found that the individual report that the tool generates for each student is very useful. When a student comes during reception hours I can take a look at his report and guide him effectively*".

"I sometimes open individual student's report to track her progress. It helps me to better understand the students and their difficulties."

According to the above excerpts we can learn that the lecturers of the two pilot groups found the assessment tool to be useful as regards to their easy access to the learning situation of their students. This information helped them to better monitor their instruction in order to address students' difficulties.

2. Setting Criteria for the Assessment Process

"*Before using the tool, I didn't plan the homework assignments in advanced and I didn't set criteria at all. I mainly focused on correctness and when I noticed problems concerning other aspects like readability and modularity I wrote few comments and maybe reduced 1 or 2 points for that*".

"*With the assessment tool I invested some thinking on the criteria and assigned them significant weights. I must say that the quality of the solutions improved significantly during the semester, and I think that the improvement can be attributed mainly to the fact that the students knew the criteria in advance and adjust their efforts accordingly*".

"*I adjusted the weights of the criteria from one assignment to the next. For instance, when I noticed that after 3 assignments most of students learned to provide a clear sketch of the problem, in the 4th assignment I reduced the weight of this criterion and shifted the leftover to other criteria*".

In the above excerpts the teachers of the two pilot groups refer to activities they avoided before using the assessment tool such as planning in advance the course assignments, setting criteria set and relative weights for their assessment, saying that their investment in planning the courses' assignments and acknowledging the students in advance regarding the criteria set by which their assignments will be assessed, significantly improved the quality of the students' work. The ability to view the criteria set and weights and the students' progress in each criterion enables teachers to achieve their educational goals by adjusting the relative weight of the criteria according to the students' strengths and weaknesses.

3. Tracking the Learning Situation of the Class

"When I saw that many students failed to provide good solution to a certain problem, I solve the problem in class and emphasize the aspects that were not addressed properly".

"The graph that presents the class progress helped me tracking the 'average understanding' of the class and influence the time I spend on each of the taught issue".

"The histogram that presents the score distribution of the assignment across the various criteria provide me an immediate feedback concerning the class".

In the above excerpts the teachers refer to the advantages encompassed in the graphical abilities of the assessment tool asserting that these abilities helped them to be more alert as to their students' learning situation.

4. Working with the Assessment Tool

"*I found the excel-based tool to be very convenient to use. Everyone knows excel and therefore it was a good choice. Scores and comments are fed into excel cells, and graphs are generated based on these data*".

"*The task's sheet is very easy to use. Almost everything is done automatically including the creation of the problems-criteria matrix, the task's sheet, and the reports. I just needed to feed the scores in and the tool provided the rest".*

In the above excerpts refer to the assessment tool's accessibility which is excel based. The fact that excel is part of the office suite enables easy installation and convenient operation of the assessment tool.

B. Students' Perception

Analysis of the students' responses to the question "describe your experience with the assessment tool", revealed the following issues: reference to the tool's constituents and reference to the assessment process.

1. The Tool's Constituents

Many of the students made statements similar to the following:

"*This is the first time that the feedback refers to all criteria explicitly for each problem! Each score reduction is justified. I feel that my work was reviewed thoroughly and with full attention*".

"*I usually forget the grades I receive in my homework assignments, and forget easily the reasons for loosing score. But this time I could easily remember all the scores and all the reductions, since they were included in each report*".

"*The combination of literal and visual feedback is perfect for me. I watch the graphs to examine my scores and read the comments to understand the score reductions*".

"*The graph that presents the relative score compared to the rest of the class is most useful to me. I'm very curious about my relative achievements and find it more important than the absolute grade. The higher my relative scores the higher my satisfaction regardless the absolute value*".

"*The graphs that present the progress along the course tasks provided me a great way to track my achievement and to identify my weak areas. I immediately found these weak points in the graphs and could focus my efforts to improve my understanding of these issues*".

Most of the students referred to the graphical presentation of the feedback assessment according to the categories saying that it helped them to monitor their efforts to the categories in which they encountered difficulties. Moreover, they pointed out the advantage of receiving all the grades accumulated along the course timeline so that they could track their learning situation.

In the traditional assessment process usually the feedback students receive on their homework includes summative grade for all the included problems and few justifications to explain the grade reductions. In such assessment process it is difficult for the students to figure out what are the specific issues in which they have difficulties. The suggested tool enables the student to follow each criterion in each problem within a certain task along the various homework assignments during the course timeline. The different forms in which the students' progress is presented, helps them realize their accurate learning situation in each of the assessed criteria. The assessment tool also provides the students with the information regarding their relative position in class which can serve as a learning catalyst and motivation for better success. Students tend to appreciate rich and meaningful feedback attached to the scoring of their homework assignments, and feel disappointed otherwise [17].

2. The Assessment Process

Many of the students made statements similar to the following:

"*Knowing the assessment criteria in advance helped me to improve my answers in all aspects. For instance, I made several passes on the code before submitting; added comments to the code changed variables' names and even broke down long and complex methods into several simple ones just to make sure that I'm not going to lose score for sloppy submission. It surely improved the quality of my solution*".

"*When I had to provide a geometrical proof, I saw that the criteria list includes various aspects regarding geometrical proofs such as clear sketch, accurate references of mathematical theorems, justifying each claim and so on. This list helped me both to learn about the important constituents of proof and to properly apply it*".

"*I was quite surprised when I saw the heavy weights the lecturer assigned to the readability modularity and coverage criteria. I'm not saying that these criteria are not important, but in the first programming course correctness was the only issue. I had to adapt my coding style to the new requirements*".

"*The lecturer explained at the beginning of the course that good solution refers to more aspects than its correctness. At first I didn't understand the importance of it but according to the criteria I invested some thinking to provide clear sketch describing the solution, justify each claim in the proof, and use accurate references to known theorems. Now, at the end of* *the course I can say that I understand much better why these proof's aspects are significant*".

"*By assigning heavy weight on the coverage criterion, the lecturer forced me to test my solutions over and over. Indeed I found many software bugs that I wouldn't find otherwise. I really understand now the importance of these tests, and I thank the lecturer for that. I'm sure that when I'll write code in the future I will invest more time for testing. It pays off*".

In previous courses the students' assignments were graded mainly for their correctness, and as a result they did not pay much attention to the other aspects. According to the requirements reflected by the weights assigned by the lecturer they had to change their perception on these criteria and indeed provided better solutions. The students understood the importance of the factors that affect the quality of their solutions. Computer programming students assimilated the significance of code clarity and modularity to the future maintenance of the software and the importance of writing unit tests to cover as many lines of code as possible to reduce the number of software errors. Math students assimilated the significance of providing clear sketch, justify each claim, provide accurate reference to known theorems and arrange their proof coherently.

Notifying in advance the students about the criteria list by which they are going to be assessed has the following benefits: (1) the lecturer conveys a clear message regarding his expectations from the students. For example, if the task includes source code, through the criteria list the lecturer can convey the students the message that there are another important aspects relating to source code in addition to its correctness; (2) Acknowledging students with the criteria list according to which their work will be assessed can help them better monitor their learning. Via these criteria and relative weights they receive a clear message concerning the relative importance of a certain criterion and the amount of efforts they should invest in it.

V. Concluding Remarks

The presented results show that both students and teachers have positive experience with the assessment tool. This experience is a results of several factors stated above. Teachers can plan the assignments assign criteria and publish their weights in advance so students can adjust their efforts accordingly. After submission teacher assess the provided solutions while referring to all criteria justifying each score then distribute individual and summative reports. Teachers use the reports generated by the tool to assist struggling students and identify class weaknesses. Students receive the criteria set along with the assignment and adjust their learning efforts accordingly. They found the assessments they received to be fair and useful in a way that helped them to focus their efforts in issues they encounter difficulties. Hence, we may say that via the assessment tool the students' knowledge can be shaped. We plan to test the assessment tool on additional science courses where other criteria should be considered. We also plan to extend the tool in the following directions: (1) add summative reports for the teachers; (2) add assessment scale according to which teachers reduce points on faulty or inaccurate answers; (3) add statistics measures to compare the achievements of different groups (e.g., across semesters, across lectures).

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