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EvalVis: Enriching Formative Assessment with Visual Learning Analytics*

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The implementation of the Bologna Process has introduced continuous assessment processes, primarily formative assessment, in many Spanish universities. In such kind of scenarios, rubrics provide many benefits that can remarkably be improved using Visual Learning Analytics techniques. This paper presents EvalVis, a system that enhances feedback based on rubric assessment and visual learning analytics. EvalVis provides different visualizations for students and teachers. The visualizations included in EvalVis have been designed upon identification of visualization needs of students and teachers. The system provides students with information about their individual learning process and performance, including the capability to contextualize their information into the group. EvalVis also allows the teaching staff to monitor different groups of students and compare their evolution and performance. The enriched feedback provided by rubrics and visualizations will help users to better understand and improve the learning and assessment processes in order to improve them. EvalVis has been evaluated to check whether it covers the identified needs obtaining very good results.

Keywords: formative-assessment; visual learning analytics; rubrics; open learner models

1. Introduction

The Bologna Process entailed the definition of new degrees and the adaptation of existing ones to the European Higher Education Area, as well as the disappearance of old study plans. The implementation of the Bologna Process at the authors' institution has involved the introduction of active learning methods and continuous assessment systems and also the adoption of competency-based learning approaches [1]. The authors have worked on different educational innovation projects in the Computer Engineering Degree, ranging from the use of educative robots or educative visual programming environments [2, 3] to the improvement of mentoring and assessment of Final Degree Projects [4]. All these innovations rely heavily on the use of formative assessment. Formative assessment aims to modify the learning process and provide information to students [5–7] directly by lecturers or derived by students through observation of assessment related data [8]. To support formative assessment, lecturers require tools that help them to perform the assessment and monitor the learning process without remarkably increasing their workload [9].

Although there is no conclusive evidence that the use of rubrics enhances student performance, assessment rubrics are an appropriate tool to help providing students with formative feedback [10], while suiting any Learning Theory [11–13]. The use of rubrics as grading tools is becoming more and more popular because they lay out the specific expected results of an assignment, encouraging consistent grading and increasing objectivity in the assessment [14, 15]. Rubrics are also helpful tools for feedback processes where the student receives all the necessary details about the goals that he or she achieved or not in the assignment, even including suggestions (in the form of the higher levels of descriptions) as to how it might have been done better [16]. Rubrics exhibit many characteristics that make them appropriate for learning in combination with other meta-cognitive activities such as self-regulation or self-assessment. Rubrics have proven to be useful for planning and self-regulation [17], whereas self-assessment rubrics have shown improvements in students' self-efficacy [18–20].

However, rubrics present some limitations as they do not provide any information about the student overall behavior during the course, and they do not allow contextualizing the student evolution and comparing it to the evolution of the group the student belongs to. In this sense, the feedback provided by rubrics can be considerably enriched opening the Learner Model (OLM) using Visual Learning Analytics (VLA) techniques.

As stated in [21], visualization is an important part of learning analytics [22], a discipline that pursues the improvement and understanding of learning and its processes. Visualizations can support the two main actors involved in educational environments—students and teachers—in several ways. On the one hand, visualizations can help students to self-reflect about their learning process [21, 23] and even incite them to take remediation actions in order to improve their performance [24,

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25]; on the other hand, they can also help teachers to design and improve their pedagogic interventions [25, 26].

The main goal of this work is to develop a tool (EvalVis) that allows to monitor students and groups of students using VLA and OLMs in order to provide teachers and students with useful information. This information promotes self-reflection and can motivate taking remediation actions in order to improve the performance of the students.

This paper discusses the requirements of course monitoring systems, followed by a presentation of the visualization functionalities of EvalVis providing use examples. Next, the evaluation carried out to validate EvalVis is presented and finally some conclusions are drawn.

2. Requirements of course monitoring systems

There are two main actors involved in any educational process: students and lecturers. Prior literature has analyzed the requirements that a monitoring system should cover by observing the objectives of lecturers and students when monitoring the students [24, 27–29], identifying that the main requirements and needs of users are related to student performance and student assessment [27].

The literature highlights the following requirements for both students and teachers:

- Observing the evolution along the course: Any student needs to observe and monitor his or her evolution throughout the course. From the teachers' perspective, any lecturer requires the capability to supervise how each student or group evolves.
- Observing performance in particular aspects: Students need to observe their performance in any particular graded task. Analogously, lecturers might want to analyze performance on each particular grading aspect either for an individual or for a group of students.

This information increases motivation, engagement and student reflection, which in turn provides a greater control over their learning to students, facilitating decision-making processes [21]. In more recent works, the importance of extending Open Student Models with social aspects has been pointed out, introducing the so-called Open Social Student Model (OSSM) [30, 31]. Furthermore, some researchers have observed an increase on student engagement and learning effectiveness using those models [30, 31]. Therefore, a monitoring system should provide users with the possibility of contextualization:

- Contextualizing student data: Students need to be able to contextualize their evolution along the course or performance in a particular task in relation to the rest of the class. Similarly, teachers need to contextualize the evolution or performance of particular students in a group context.

Apart from individual needs, regarding the social aspect, teachers have the following additional requirements when using a monitoring system:

- Comparing group data: Teachers need to compare the evolution along the course of different groups of students and their performance in any graded task or assignment.

When rubrics are used for assessment, visualizations of performance on a specific task or assignment may be shown by highlighting in the rubric the level of achievement on each dimension and the score (see Table 1). This way, every student may know the expectations he or she has fulfilled, as well as the level of achievement attained in each of the grading dimensions.

Although the visualization shown in Table 1 presents the grade along with clues that might help

Table 1. Traditional rubric visualization for the assessment of an oral presentation

	Excellent	**Advanced**	**Average**	**Developing**	**Beginning**
Content	Shows a full understanding of the topic	Shows a very good understanding of the topic	Shows a good understanding of the topic	Shows a good understanding of parts of the topic	Does not seem to understand the topic
Organization	Presentation has a clear, logical order throughout	Presentation order is mostly clear. The speaker may skip around once or twice	Presentation order is mostly clear. The speaker may skip around several times	The speaker skips around many times. Speech sounds choppy	Little or no clear order is evident in the presentation
Communication skills	Speaks clearly and distinctly all of the time	Speaks clearly and the majority of the time	Speaks clearly and distinctly most of the time	Speaks somewhat clearly some of the time	Often mumbles or cannot be understood
...	...	...	...	...	...
Grade: 6.5					

the student to achieve higher grades, it does not provide any information about the performance compared with the group or the evolution of the student. This information can be incorporated by opening the learner model using Visual Learning Analytics (VLA) [21, 32]. Open Learner Models (OLMs) provide the students with means to access information about them, promoting learners' self-reflection by confronting them with representations of their understanding. Additionally, OLMs enriched with information about group performance foster student motivation and competition among them, which may affect positively the learning process [32, 33]. All these characteristics make OLMs extremely helpful for formative assessment as allowing students to observe, analyze, and assess how well they are learning is a key aspect of learning processes [34].

From the teachers' point of view, VLA and OLMs (including group information) can provide further insight of what is happening in the learning process that could be hardly obtained otherwise from the traditional rubric visualization. For instance, traditional rubric visualizations do not facilitate observing overall student group knowledge or skill improvement during the course. Furthermore, if the teacher wants to visualize the whole performance of the classroom in a particular assessment, the most common visualization consists on showing average grades or similar methods. However, those visualization methods do not allow to observe and analyze the weaknesses and strengths of the group in the different areas or dimensions of the graded work.

We have developed a system that combines OLMs and VLA techniques in order to cover those requirements called EvalVis, which visualization features are detailed next.

3. EvalVis

EvalVis is a system developed to cover the previously detected requirements combining OLMs and VLA techniques. In order to do that, it relies on different visualizations. The visualizations provided by EvalVis are related to the four requirements identified in the previous section: observing the evolution along the course (section 3.1), observing performance in particular aspects (section 3.2), contextualizing student data (section 3.3) and comparing group data (section 3.4). In addition, the user can navigate through the different visualization options to get more detailed information. For example, when visualizing the information of a particular student the contextualization of the student among the group can be easily consulted just clicking on the corresponding button (Fig. 1 D). This information is provided to users from two different perspectives. The first one is related to the classical task or assignment perspective, whereas the second one is oriented to those teachers that follow competency-based learning.

To ensure usability and make the navigation easy for users, all graphical interfaces of EvalVis share the structure shown in Fig. 1, which entails four main components. In the upper left hand of the window, the user can choose the Task or Competence perspective (A). As the users might have different preferences regarding the visualizations provided by EvalVis, the system is capable of showing to each user his or her preferred kind of visualization by default whereas the rest of possibilities are accessible through the system options (B). The main frame presents the information (C). Finally, the user can determine if the information must be contextualized by adding group information to the visualization (D).

An analysis of the literature regarding the kinds of visualizations that can be used to present the information required by the students and teachers in formative assessment contexts has been carried out. Many authors (e.g., [35]) suggest that visualizations such as point-like plots are more adequate to present values when there is not order among the x-axis elements or the order is not relevant. On the other hand, line plots are appropriate to show trends along the time. Bar plots can be used to represent values but are also appropriate to represent value distributions per intervals or through different alternatives. Therefore, visualizations such as bar plots and radar plots are used in EvalVis to provide information about students and groups whereas line plots are used to present the evolution of students or groups along the course. Bar plots are also used to present score distributions per performance levels in rubric-based assessments. In addition, group information has been enriched with

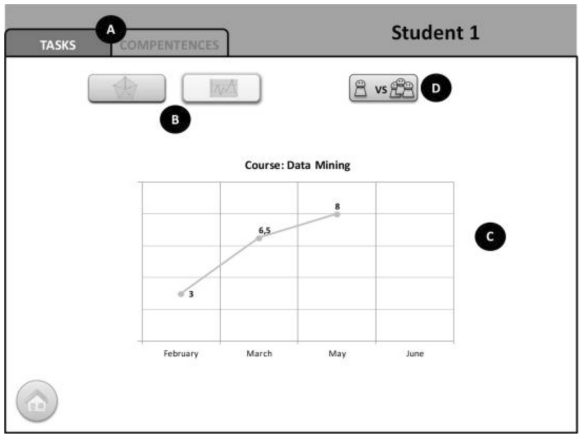

Fig. 1. Structure of EvalVis' screens.

violin plots which are used to present group information as they show the tendency and spread of the grades by combining boxplots and density plots.

The following sections describe the visualizations provided by EvalVis, organized according to the categories mentioned before.

3.1 Observing evolution along the course

As seen in section 2, the first requirement related to observation of evolution along the course. For both students and teachers, the evolution includes graded tasks and the achieved mastery level in the competencies of the course.

3.1.1 Evolution from a task perspective

EvalVis provides different means to present the evolution of the students regarding the grades obtained in the course's tasks. As mentioned before, when the assignments' order is not important, radar plots are more appropriate to show the

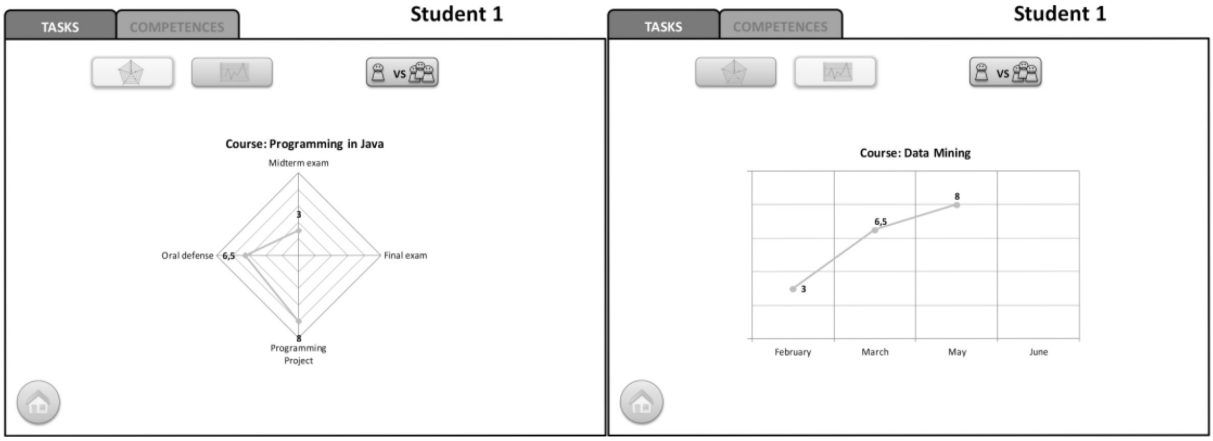

Fig. 2. Evolution from a task perspective according to differenk kind of tasks (left) or according to periodical tasks (right).

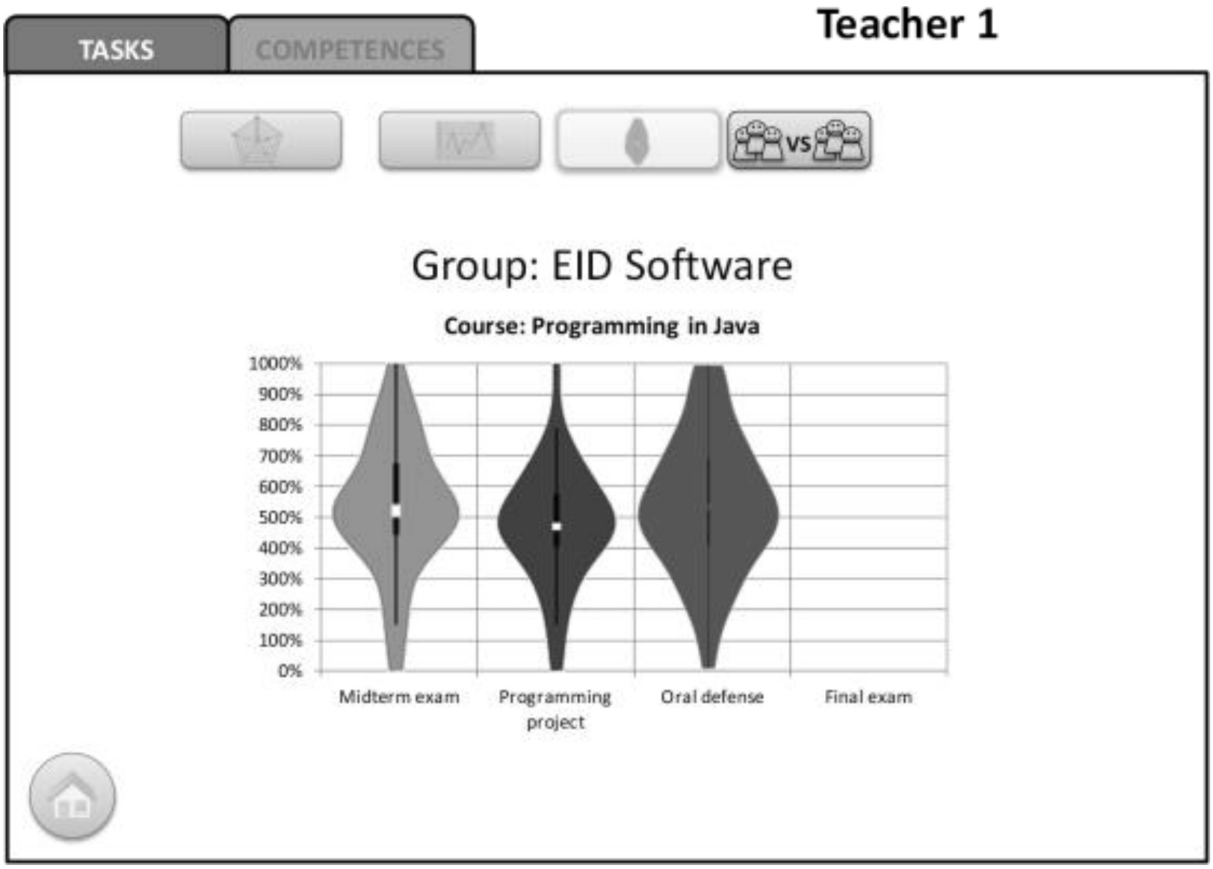

Fig. 3. Evolution of a group according to tasks.

performance of the students, whereas line plots are more adequate to show the trend or evolution along the time, for example, in periodical assignments (see Fig. 2).

EvalVis also allows teachers to observe the evolution of a given group of students from a task perspective. To this end, EvalVis provides similar plots to those used for individual students, showing the average score of the group in each assignment. This approach is quite restricted because it does not provide enough information of the group. In order to provide more detailed information about the evolution of the group, EvalVis also provides violin plot-based visualizations, which shows the grade distribution too (see Fig. 3).

3.1.2 Evolution from a competence perspective

EvalVis may also show the evolution of competences acquired. Fig. 4 shows the two plots provided by the system. In both cases, the plots show student achievement level in each competence. The user can choose which particular competence or competences wants to visualize by selecting them in the corresponding check-boxes in any moment.

EvalVis also presents the evolution of a group of students attending to a competence perspective. In this case, in addition to the line plot and the radar plot, it also provides violin plots in order to show more information about the performance of the group. All these plots describe the achievement levels of the group regarding the different competences.

3.2 Observing performance in particular aspects

To better understand the learning process, the user can inspect the assessment of each assignment in more detail. EvalVis supplies a set of visualizations that provides student with feedback that might help them to identify their weaknesses, as well as to comprehend how to improve their learning process and implement new learning strategies. From the teacher perspective, EvalVis provides detailed information about the performance of each student and each group of students.

3.2.1 Task performance

Besides the grade obtained, EvalVis can show more details regarding the assessment of each task in

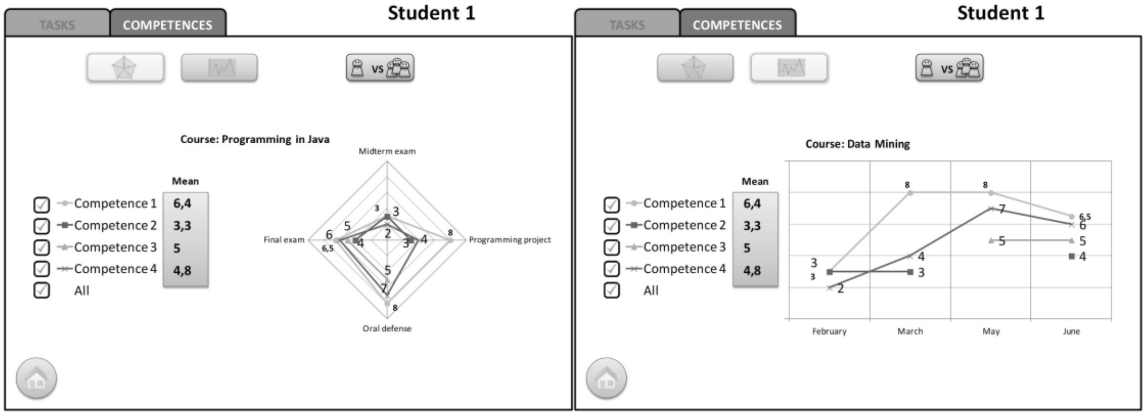

Fig. 4. Student's evolution according to competences.

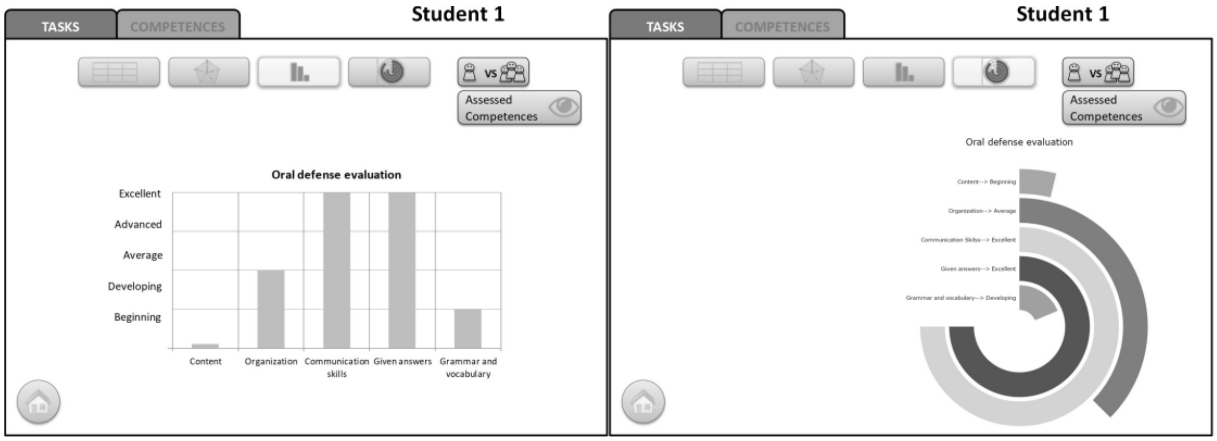

Fig. 5. Plots for visualization of performance on tasks.

order to provide students and teachers with more information that can be used to improve learning and teaching strategies. This information is provided through three different visualizations that show the performance of the student in each one of the assessment criterion considered. The first one uses a radar plot similar to that shown in Fig. 2. Besides, two additional plots, shown in Fig. 5, display information in a bar plot and a circular bar plot.

When the assessment is carried out using rubrics, the assessment criteria correspond to the rubric's dimensions. EvalVis allows to obtain further information by clicking on any of the assessed dimensions. For example, when clicking on the *content* dimension in Fig. 5, EvalVis shows the feedback about that dimension to the student (see Fig. 6). Feedback includes the excerpt of the rubric corresponding to the selected dimension and some suggestions for improvement. These suggestions can be predefined when designing the rubric and be shown to all students achieving a certain performance level, or they can be personalized by the instructor when assessing and grading a particular student.

EvalVis also provides different means to visualize group performance in a particular assignment (see Fig. 7). For instance, the teacher can use violin plots to observe the grade distribution in each dimension or an enriched rubric-based visualization that presents the average score and distribution of grades for each dimension.

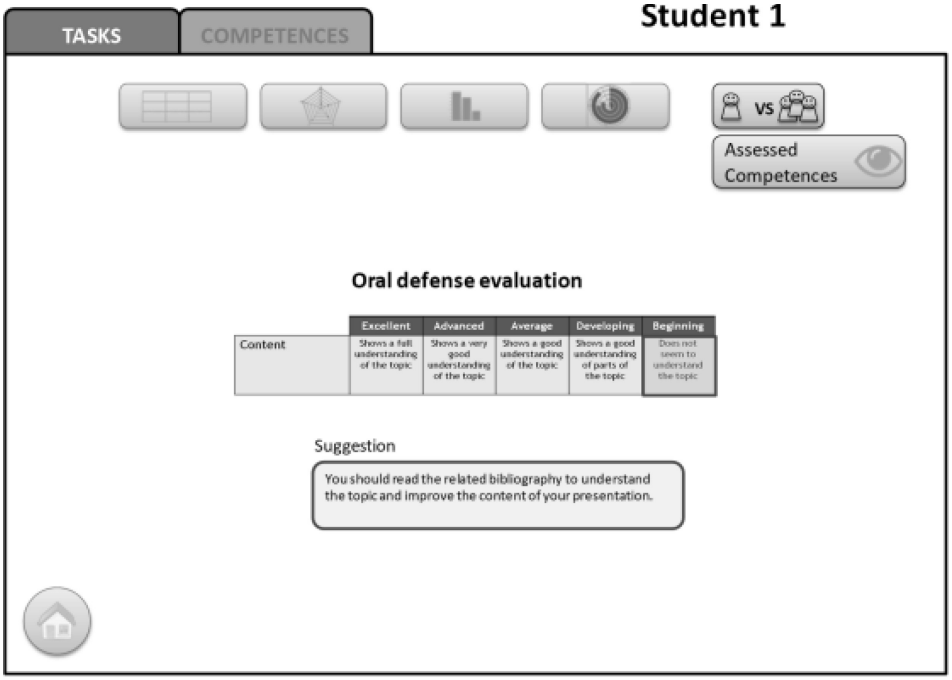

Fig. 6. Feedback example of content dimension assessment using the rubric.

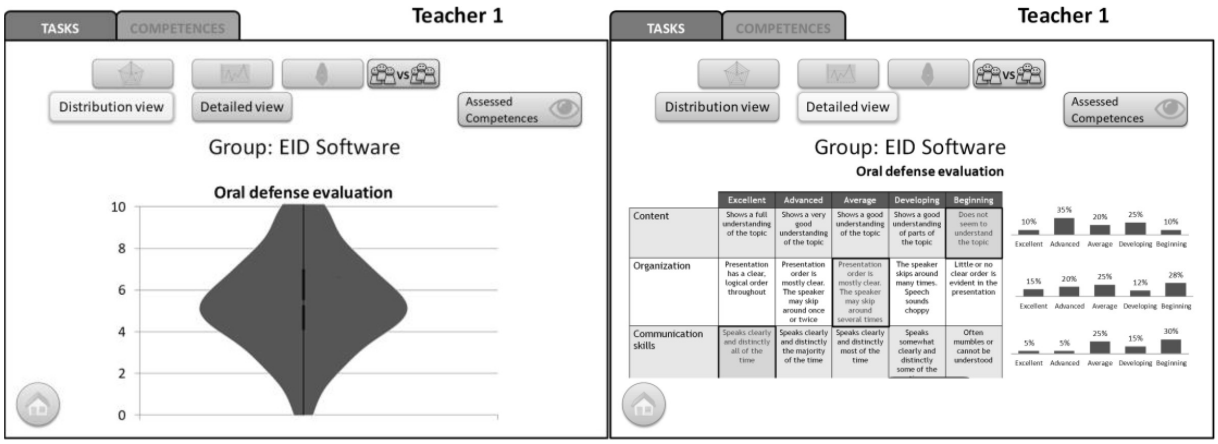

Fig. 7. Performance of a group in a task.

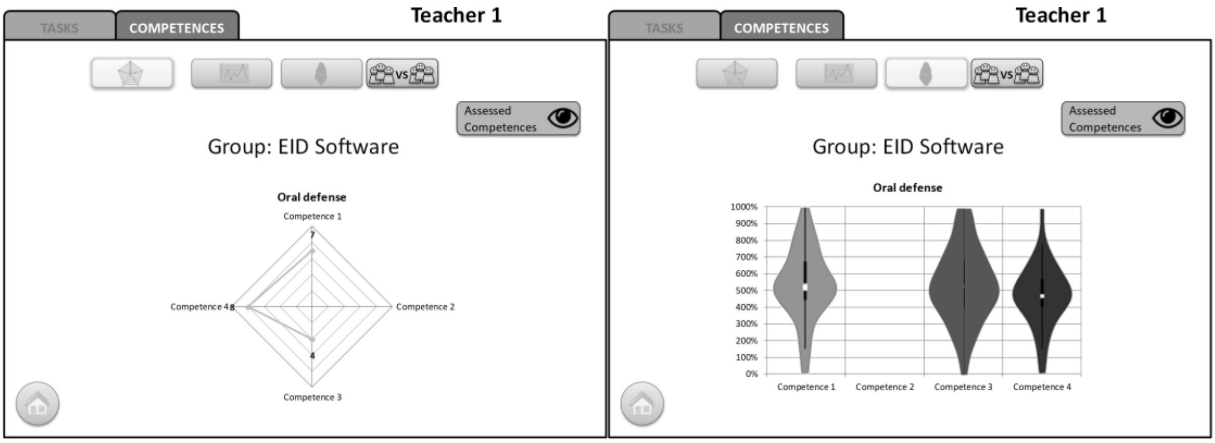

Fig. 8. Performance of a group on the competences of a task.

3.2.2 Competencies performance

In competency-based learning, each activity can be related to one or more competences. EvalVis allows inspecting the achievement level of the competences related to each activity by displaying the achievement level along with the results of the assessment. When the data correspond to a single student, the visualizations are similar to the ones depicted in section 3.2.1, showing the achievement level close to the plots.

Regarding competence achievement level of a group in a task, the visualization shows group achievement levels for each competence in various plots, including a violin plot with the distribution of the achievement levels of the group (see Fig. 8).

3.3 Contextualizing student data

Data contextualization enriches the information about evolution or performance and provides a social dimension to the classic OLM that fosters student competition and motivation [31]. This section presents and discusses the plots used by EvalVis to provide contextualization either on task or competence perspectives.

3.3.1 Contextualizing evolution

Visualizations about student evolution, both for task and competence perspectives shown in section 3.1 have been enriched with context information by incorporating the average results of the group and comparing them to those of the student (see Fig. 9). For example, Fig. 9 shows that the student's performance in the *Programming Project* task is better than the average performance of the rest of the group. Furthermore, when using the competence perspective, the student can observe and compare his or her performance on the competences with the average performance of the rest of the group.

Users can further expand on the information by clicking on any of the tasks and take a look at other indicators, such as standard deviation of the group, their grade ranking or the distribution of grades among the group.

3.3.2 Contextualizing performance on a task

EvalVis provides similar visualizations to the ones presented in previous sections for contextualization of performance in the task and competence perspectives. However, when focusing on a particular task

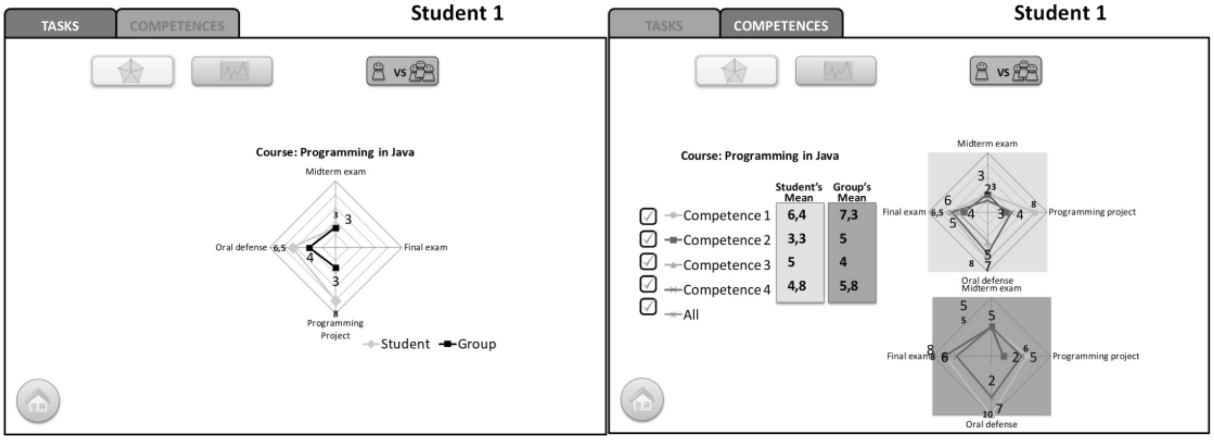

Fig. 9. Contextualizing the evolution of a student with the group through the tasks (left) and the competences (right).

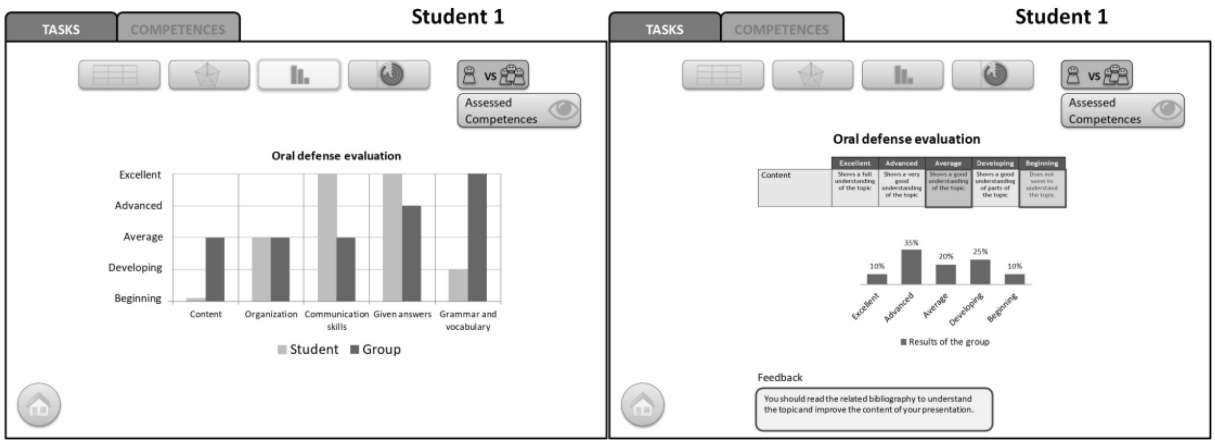

Fig. 10. Contextualizing task performance (left) and showing assessment details (right).

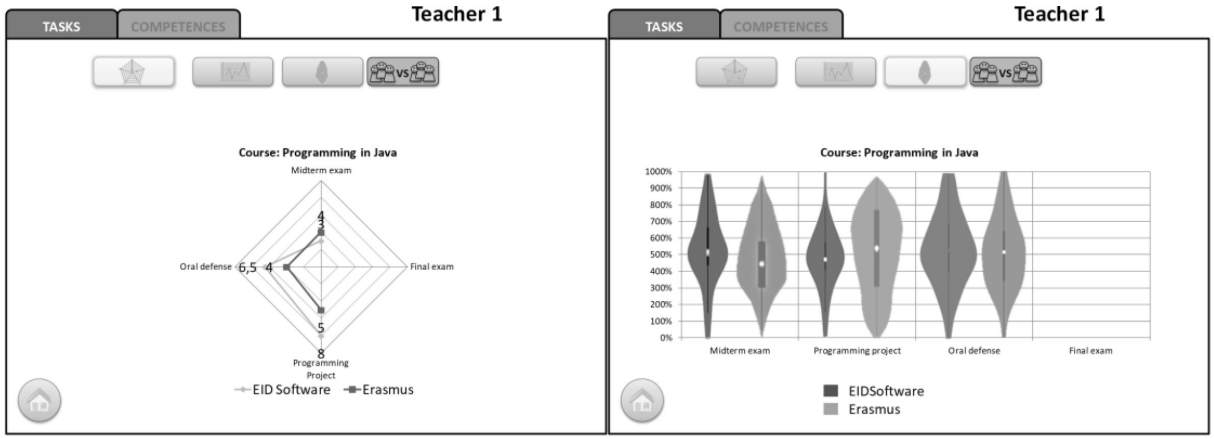

Fig. 11. Comparing evolution of groups in the tasks.

the information can be enriched with detailed information about task assessment and the aspects being considered. Fig. 10 shows that the student's performance in the Content dimension of a specific task is worse than the average performance of the rest of the group. This visualization gives the student information about the extent to which he or she is keeping up with the rest or the group, and which his or her weaknesses are. If the user clicks on the dimensions or aspects, the rubric is shown providing some clues and feedback with instructions to improve the performance.

3.4 Comparing group data

EvalVis provides teachers with a set of visualizations to analyze what is happening with different groups. Teachers can define the groups to be included in the visualization. For example, a group formed by Erasmus students and another one with local students can be compared to see whether there are significant differences.

3.4.1 Comparing evolution

Again, the system provides several visualizations to compare the evolution of different groups in the tasks. Fig. 11 shows two of these visualizations, a radar plot and violin plots. The former presents and compares the average performance of the groups whereas the latter provides more information about the groups (including the mean and the percentiles).

3.4.2 Comparing performance

When teachers detect through the visualizations that there is a problematic task (e.g., a task with poor average performance), they can get a more detailed information and facilitate assessment by comparing the results of the different groups, or even each group's achievement level of the competences related to that graded activity (see Fig. 12).

4. Assessment of EvalVis

Previous section has described EvalVis, a tool for monitoring courses that has been developed according to the identified users' requirements. The assessment of EvalVis has been carried out with the aim of answering two main research questions:

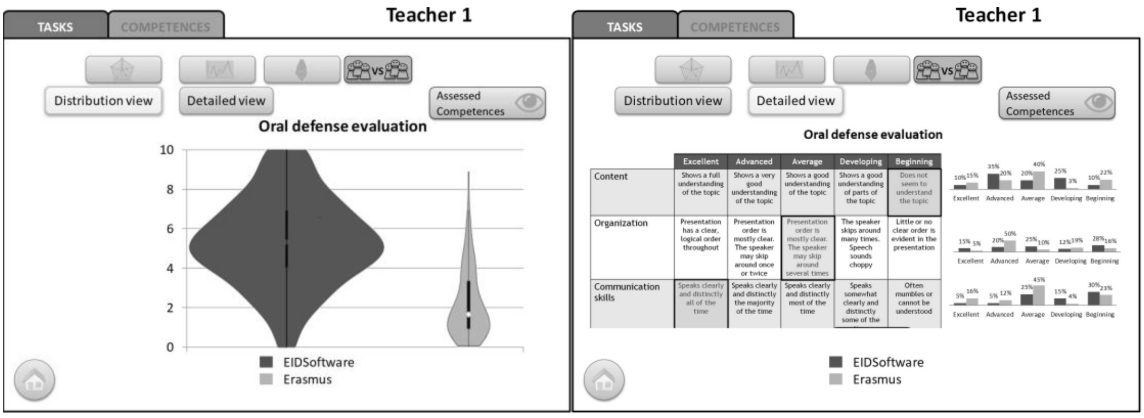

Fig. 12. Comparing performance of groups.

- Does EvalVis really cover the identified requirements?
- Which are the users' preferred visualizations? Do they change according to their profile or to the information being visualized?

In order to answer those questions, a pilot assessment study was carried out. Next, the design of the pilot study and the results obtained are described.

4.1 Design

The study was conducted using two questionnaires, one for teachers and another one for students. Each of the questionnaires was divided in two parts.

The first part of the questionnaires asked respondents about the coverage of their needs in EvalVis. This part of the questionnaires included several questions to identify whether the visualizations provided by EvalVis are useful to satisfy the information requirements defined in section 2. The teachers' questionnaire entailed fourteen 5-level likert questions, ranging from strongly disagree (1 in the scale) to strongly agree (5 in the scale) whereas the students' questionnaire contained five questions of this kind. In addition, an open-ended question was included in the questionnaire for each aspect being visualized (evolution, contextualization data, etc.) to allow users to add suggestions and comments.

Table 2 shows an excerpt of the student and teacher questionnaires that contain questions oriented to measure the coverage EvalVis provides to the established requirements.

The second part of the questionnaires was related to the user preferences regarding the kinds of plots provided to visualize information related to each of the requirements. In order to obtain this information, the teachers' questionnaire contained twelve questions whereas the students' questionnaire entailed six.

4.2 Results

Eight teachers and 18 students answered the questionnaires. Both teachers and students were from Computer Engineering degrees as the information included in EvalVis for the study corresponds to courses from these degrees. This way the participants were familiar with the context for the data being displayed and no additional explanation about the tasks or contents was needed.

Next the results obtained for each of the research questions are detailed.

4.2.1 Coverage of requirements

The results gathered from the first part of the questionnaires in the study are very positive (see Table 3). All the questions regarding the coverage of the requirements got a mean score over 4 points in a 5 points scale from both students and lecturers with a low standard deviation in all the cases. As compar-

Table 2. Excerpt from students' and teachers' questionnaires

Students' questionnaire		**Teachers' questionnaire**	
S-1	The visualizations provided by EvalVis are useful to analyze my evolution along the course regarding the tasks being evaluated	T-1	The visualizations provided by EvalVis are useful to analyze a student's evolution along the course regarding the tasks being evaluated
S-2	The visualizations provided by EvalVis are useful to contextualize my evolution along the course into the evolution of the rest of the group regarding the tasks being evaluated	T-2	The visualizations provided by EvalVis are useful to contextualize the performance of a student in a particular evaluable aspect regarding the competences being assessed into the group's performance
	. . .		. . .

Table 3. Results of the study regarding the coverage of requirements

	Teachers		Students	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
Observing the evolution along the course	4.4	0.55	4.2	0.50
Observing performance in particular aspects	4.3	0.58	4.3	0.44
Contextualizing student data	4.3	0.67	4.1	0.67
Comparing group data	4.3	0.58	—	—

ing group data is a feature only available to teachers, students were not questioned about this kind of visualizations.

In general, the valuations given by the teachers are higher than those given by the students. It is remarkable that in most cases, teachers value the coverage of the requirements better than the students for the same objectives.

In any case, the results are very good and prove that EvalVis fully covers all the requirements detected both for students and teachers. Even if students' valuations are slightly lower than teachers', this could be due to the lack of experience analyzing and visualizing this kind of data. This hypothesis is supported by the fact that when asked about visualizations not included in the system that could be considered interesting and useful to deploy the information, no answers were collected in the students' questionnaire. However, teachers proposed some improvements, e.g., adding the possibility of visualizing the information through bar plots for contextualizing a student's performance into the class or including more information in the provided visualizations, indicating in a violin plot where the student is located among the group.

4.2.2 Preferences on the visualizations

The users' preferences for visualizing the information have been derived from the questions in the second part of the questionnaires.

In the case of teachers, 49% of them prefer visualizations using linear plots, followed by violin plots (with a 24%) and letting the radar plots, with a 13%, as their third preferred visualization for the majority of the information deployed in EvalVis. However, there are some exceptions, especially, when the visualization implies data from a group of students, where the violin plot is the preferred plot. For example, to observe the evolution of a group of students along the course, 67% of the teachers selected violin plots as their preferred one.

For the students, the results are quite similar. There is no unanimity about the preferred visualization, but 39% of students prefer bar plots when this kind of plot is available. Even when visualizing the result of using an assessment rubric to assess some aspect of the course, the preferred visualization after the bar plot is the traditional one for 26% of students, whereas other kind of plots such as radar plot or circular bar plot are put aside.

It should be taken into account when analyzing the results of the study that some users are not familiar with all the visualizations provided by EvalVis. For example, from the teachers' comments in the open-ended questions it can be derived that at least a 22% of them did not understand the way a violin plot shows the information. Therefore, even if violin plots offer more information and EvalVis provides an explanation accompanying each plot, users may prefer the visualizations they are more familiar with. This has been supported by the fact that users with previous experience using visualizations opted for more complex plots such as violin plots. Therefore, it is important to include some kind of formation for the users, in order to allow them to understand all the available kinds of plots. In the case of EvalVis, each plot is accompanied by a brief explanation that users can check if they are not familiar with that visualization

Another interesting result of the study is the verification that the visualization preferences change when the data to be shown is more complex and involves contextualizing or comparing the data. For example, the preferred plot for visualizing the evolution of a group of students is the violin plot (56% of teachers), whereas when comparing the evolution of different groups, the 66% of teachers like a linear plot better. Therefore, EvalVis *adapts* its visualizations to the user preferences according to the information being visualized, not just to the user's favorite kind of plot.

Regarding the type of information students and lecturers prefer to visualize, in both cases the majority of the users (45% of teachers and 59% of students) answered that they will equally use the tasks or the competence perspectives. For those teachers that prefer one perspective to the other, the preferences for each perspective are quite balanced (33% for the task perspective, 22% for the competences perspective). In the case of students, the result is very unbalanced; only a 6% of students prefer the competences perspective, whereas a 35% of the students prefer the tasks perspective.

5. Conclusions and future work

This paper presents EvalVis, a system that enriches formative assessment environments by opening the Learning Model of the student using Visual Learning Analytics techniques and adding social features, which have proven to support decision making processes by fostering learner reflection together with planning and monitoring capabilities. EvalVis also fosters teachers' reflection and decision making processes offering visual ways to display and analyze the information regarding the assessment.

EvalVis provides information to users using different types of plots and allowing user-navigation, which offers various visualizations for the same information in order to better adapt to different user preferences. The visualizations provided by EvalVis have been enriched with contextualization information to improve reflection and promote decision making.

EvalVis has been evaluated through a pilot study where both teachers and students indicated that the system successfully covers their assessment data visualization requirements and, therefore, offers them the information they need to reflect about their learning and teaching processes in order to improve them.

The study was also used to know the users preferences regarding the way the information should be displayed, i.e., the kind of plot they like more. It has been concluded that users tend to prefer the visualizations they are more familiar with, even if there are other visualizations containing more information. The study also showed that the users' preferences might vary depending on the type of information they are visualizing.

The use of EvalVis will be broaden to other courses of Computer Engineering and other contexts, and its assessment will be extended to new users and new visualizations. As the number of users increases, an assessment of the impact in the learning process of the use of visualizations in a formative assessment environment will also be conducted.

In addition, a rating monitoring tool will be integrated into EvalVis to analyze the assessments and to identify rater effects. Detecting rater effect is necessary to take actions to guarantee a fair assessment for all the students. Furthermore, performance-predicting techniques will also be incorporated, specially, for early detection of students in risk of failure so that remediation measures can be taken at early stages of the course.

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