



TECHNISCHE UNIVERSITÄT MÜNCHEN
DEPARTMENT OF INFORMATICS

BACHELOR'S THESIS IN INFORMATICS

**Improving eLearning through statistical
Feedback**

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Eine Verbesserung von elektronischem Lehren und Lernen
mithilfe von statistischem Feedback

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I confirm that this thesis is my own work and I have documented all sources and material used.

Garching b. München, June 15, 2017

Signature

Abstract

The goal of this thesis is to improve the learning process of all participants in two practical courses. The courses are called ilab1 and ilab2 and are currently conducted at the Technical University of Munich.

To reach this goal, we implement graphical visualizations of statistical data gathered from the two courses. Performance indicators, such as time spent and results achieved, are considered. These indicators are a form of feedback which helps instructors to recognize problems and adapt the contents of the courses. The visualizations contribute to improving three requirements for creating a good learning platform. Namely - simplicity, interactivity and diversity. The visualizations increase the understanding of the learning process and as end result shall also lead to an increase in the motivation of the participants.

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Chapter 1

Introduction

1.1 Goals of the thesis

The objective of this Bachelor's thesis is to support and improve the learning process of eLearners¹, content creators and instructors in two practical courses. The courses are called ilab1 and ilab2 and are currently conducted at Technical University of Munich (TUM). They are running within an electronic learning (*eLearning*) environment called "labsystem", which is based on PHP. This environment is implemented and currently maintained as an open-source project² by Marc-Oliver Pahl and Lukas Schwaighofer.

In order to reach the goal of the thesis, existing eLearning supporting statistics are assessed. Furthermore, feedback elements for visualizing statistical data are implemented and evaluated. For the evaluation, data is being gathered from the two ilab courses. More specifically, performance indicators, such as time spent and results achieved, are visualized. Collecting and graphically visualizing gathered data aims to ease and improve the tutoring process, as well as the learning process of students. To better explain the purposes of such visualizations, two concrete examples follow in the next paragraph.

On one hand, marking and showing worst answered questions to instructors shall help recognizing content problems and deficiencies by different exercises. Visualizing approximate time spent on an lab exercise, on the other hand, can help tutors to recognize time related issues. Both visualizations shall enforce according changes to problematic tasks and allow tutors to explicitly emphasize on misunderstood content. The end goal is to increase students' understanding of the process and their motivation.

¹Learners using electronic or digital media in their learning process

²<https://github.com/m-o-p/labsystem> [1]

1.2 Outline

The thesis is structured as follows. The Analysis (Chapter 2) starts with a review of the concrete structure, functionality and feedback elements of the labsystem. After that follows an explanation of what eLearning is and why it has established itself as an efficient educational means. A motivation about how a learning process should be structured is given and reasons behind different platform design decisions are explained. Feedback is examined as most important learning mechanism and on base of the existing feedback elements in the labsystem, a set of basic feedback mechanisms is considered in detail.

Considering the requirements for a good learning process (2.3.1), a concrete observation of the labsystem, as well as at the Coursera, edX and Moodle platforms follows. Focus of interest are the implementation features which their basic feedback mechanisms provide in order to fulfill those requirements. Those features are structured in a taxonomy. This taxonomy is then used to compare the labsystem and the platforms in the Related work part of the thesis. This is done in order to determine if any important features are missing in the labsystem. Considering our existing implementation ideas, it is interesting to see if something similar to them is already implemented in the other systems and if yes - how.

In Chapter 3 are discussed the Coursera, edX and Moodle eLearning platforms. The features they offer and their Privacy Policies are reviewed. Questions regarding the nature of data the systems are gathering, to whom this data is being visualized and for what purpose are considered. This aims to give an introduction and general knowledge about each system. Then their feedback elements are reviewed in detail and an "assessment" of each system is presented according to the taxonomy (2.5.1), defined in Chapter 2.

At the end of Chapter 3 a structured comparison overview of the differences between all platforms is presented. More specifically, an overview of missing features (from the taxonomy 2.5.1) in each system. A conclusion is made about the state of the labsystem. The reasons behind our choice of artifacts to design and implement are also explained.

In Chapter 4 each artifact is discussed in detail. The chapter considers to whom each artifact shall be visible, with what purpose, which concrete design features contribute to this purpose. Furthermore, what input is needed to implement those features and what is the processing algorithm for the creation of each artifact. Under consideration are taken both artifacts that are implemented, as well as artifacts which remain as possible future work.

In Chapter 5 is discussed the logic behind the implementation of the artifacts, presented in Chapter 4.

In Chapter 6 the implemented artifacts are evaluated. We reason about if they fulfill their purpose and about how do they perform.

Finally, the thesis is concluded in Chapter 7, where our findings are summarized

and possible future work ideas are discussed.

1.3 Methodology

Figure 1.1 consists of two consequent parts and shows the logical connections between the different contents in the thesis. With red are depicted the main questions/topics and with yellow - the subtopics in the Analysis and Related work part. The blue nodes mark the transition to the Design part, with purple - to the Implementation part, with green - to the Evaluation part and with white - to the Conclusion. All subtopics in those parts are again depicted with yellow. One-sided arrows characterize one-way connections. This means that statements and conclusions made in one topic, are taken and used as input in another one. When the arrows are double-sided, this means that the topic are interconnected. Statements and conclusions from both topics are used as input in the other one for further discussion and conclusions.

The first half of the thesis introduces the environment, in which the new features are implemented and motivates why would such features be advantageous for the courses. The second half of the work presents the concrete design, implementation and evaluation of the new elements.

More specifically, the Analysis part of the thesis introduces the labsystem and eLearning. It derives goals of feedback and features of feedback elements, which eLearning platforms should fulfill and posses. Those are then structured in taxonomies. The features-taxonomy are used to compare the labsystem, Coursera, edX and Moodle. At the end of the Related work the focus on a concrete list of artifacts is grounded.

The audience, purpose, visualization and processing algorithm of the chosen artifacts are discussed in the Design. Three of them are implemented. The logic behind their implementation is described in the Implementation part.

The rest of the thesis consists of evaluation of the implemented elements, a conclusion and possible future work.

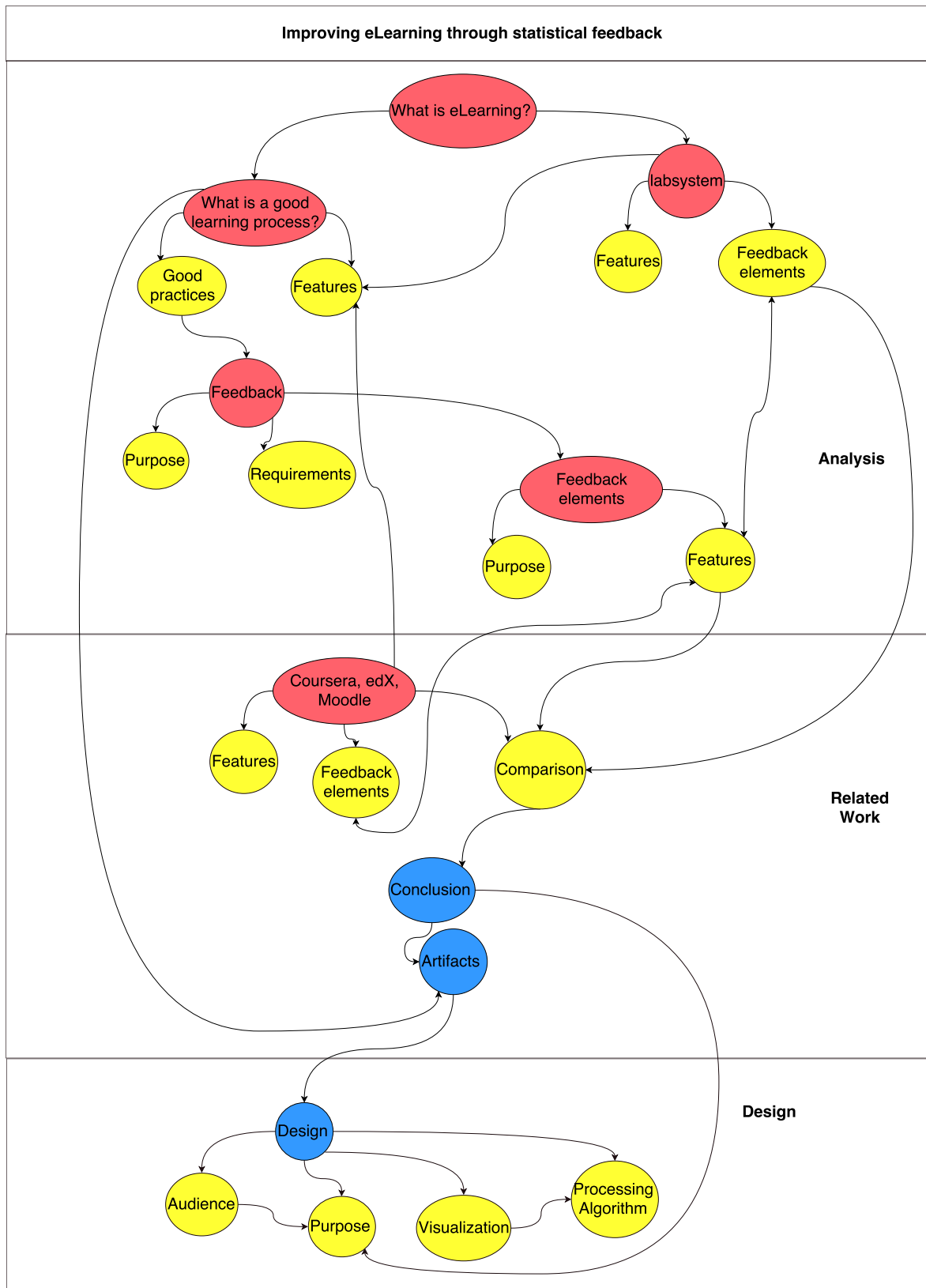


Figure 1.1: Methodology - part 1

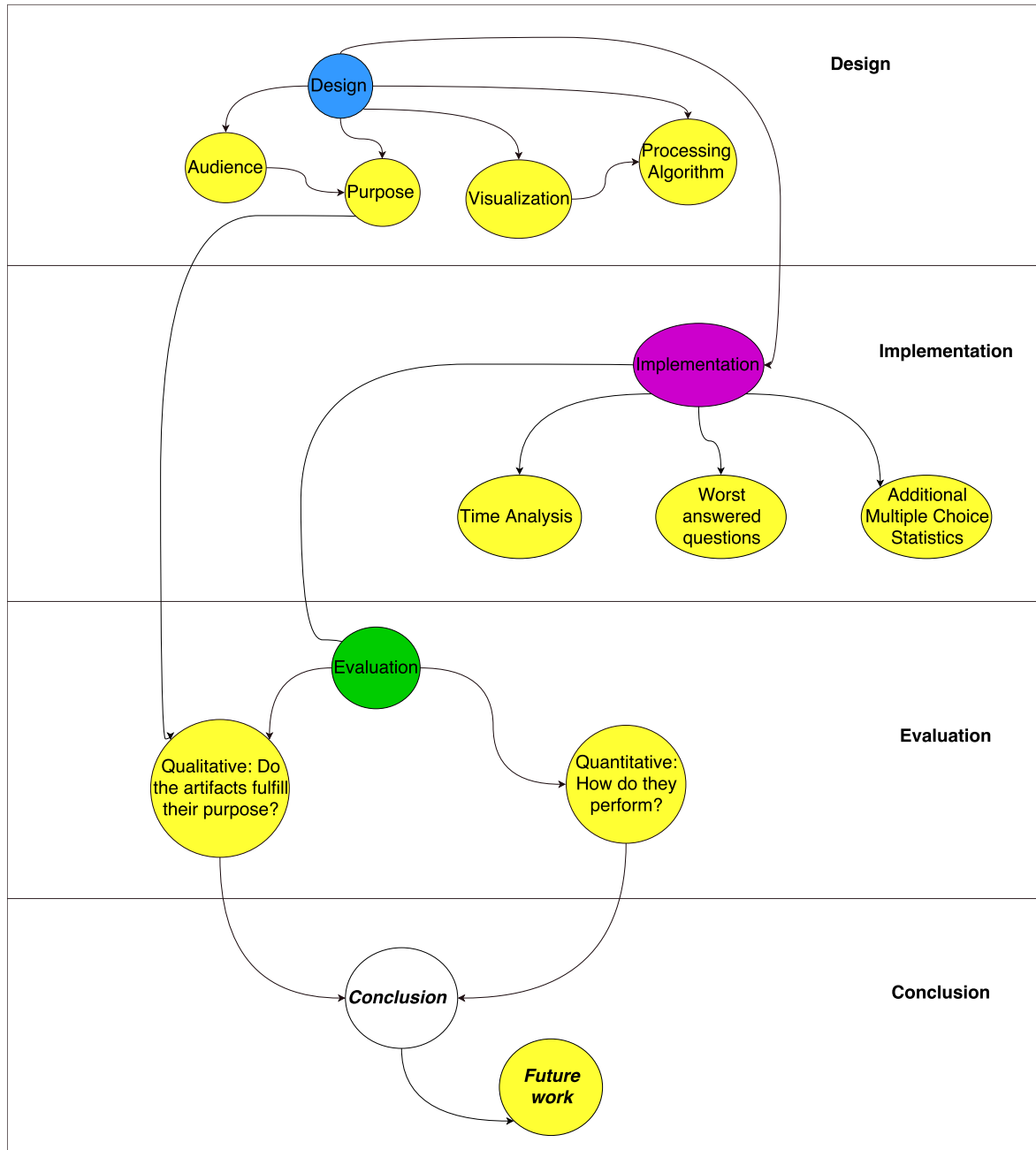


Figure 1.2: Methodology - part 2

Chapter 2

Analysis

The development of technology nowadays has led to transformations in all aspects of our lives - from the smart phones we own, through the self-driving cars we use, to the smart offices we go to work to [9]. These innovations, in my opinion, have also provoked a change in our perception of education and created the need for new methods to support learning. In this context eLearning presents itself as a way to flexibly adapt the educational structure to fit the new needs of the learners.

In this chapter the usage of eLearning is explained and motivated. Furthermore, the domain for the new elements - the labsystem platform, is examined. Criteria for a successful (e)Learning process is also identified. This leads to the role of feedback as an important support mechanism in eLearning platforms. Considering the structure of the labsystem, a set of basic feedback elements is reviewed in detail. This then helps to reason about missing elements in the platform. It also helps to justify our design and implementation choices in a later chapters.

2.1 Definition of eLearning

We start with an explanation of what eLearning actually is and what its purpose is.

The term eLearning describes all forms of learning, by which educational processes are made available through the usage of electronic or digital media [10]. In his book “Managing E-Learning: Design, Delivery, Implementation and Evaluation” Badrul H. Khan describes it as an “open, flexible and distributed learning environment” [11].

The main idea of eLearning is to motivate the learners’ own desire to improve and develop their ideas. It allows them to be independent from limitations presented by the traditional, more teacher-controlled education. It gives them opportunity to participate in classes regardless of location and time constraints. It enables everybody to gain new knowledge by following their own plan at their own pace.

In my opinion, because of its flexibility, eLearning and herewith eLearning platforms have become of interest to nowadays learners.

2.2 labssystem

In this section we review the labssystem, its features and feedback elements. It is necessary to research and assess its already existing elements, in order to be able to compare them with those which other platforms offer. This comparison then helps us to make conclusions about which further elements can be added to the labssystem platform.

The numbering, which the reader observes in this section (2.2), is a list of general requirements and best practices explained in section 2.3. Here it is used to link concrete features in the labssystem to this list. We want to show how those general practices and requirements (2.3) are fulfilled in the labssystem.

2.2.1 General description

The labssystem is an eLearning platform for course and content management. It was created by Marc-Oliver Pahl in 2003 and is used by the Technical University of Munich for the creation of two practical courses called ilab1 and ilab2.

Its functionality is well documented and explained in a number of video tutorials (2.1b), and can be divided into three main categories of features: features useful for students (learners), for tutors (correctors) and for instructors (advisers).

The system allows learners to have a preparation period, during which they have the opportunity to gain theoretical knowledge at their own pace. However, a certain time constraint, for example one week, could be set by tutors/authors using the option for locking elements of the system until a certain condition is fulfilled, for example, until all participants have answered a list of questions. Different contents and exercises can also be exported and reviewed offline as a virtual book, using the “ePub export” feature. This frees learners from location constraints.

The labssystem offers fully customisable menus. They allow individual adaptation of the structure and access rights (2.6b) of different elements. This allows creating an intuitive interface (2.1a). It is helpful when certain contents need to be kept invisible for students. For example, when tutors have implemented some improvements, but want to test them for a time period before placing them at students’ disposal.

The platform also allows cross-correction (Figure 2.1). This means that tutors can review the answers of all participants for each question. In this way the workload increases only slightly when more participating teams are added. Tutors can recognize when there are similarities in the answers and when the same problem is occurring by many teams. This helps for adjusting the grading system and giving consistent feedback.

Information about which answer belongs to whom exactly is initially hidden. Only the team number is shown by default. Names can be seen when explicitly checked. This supports a level of objectivity.

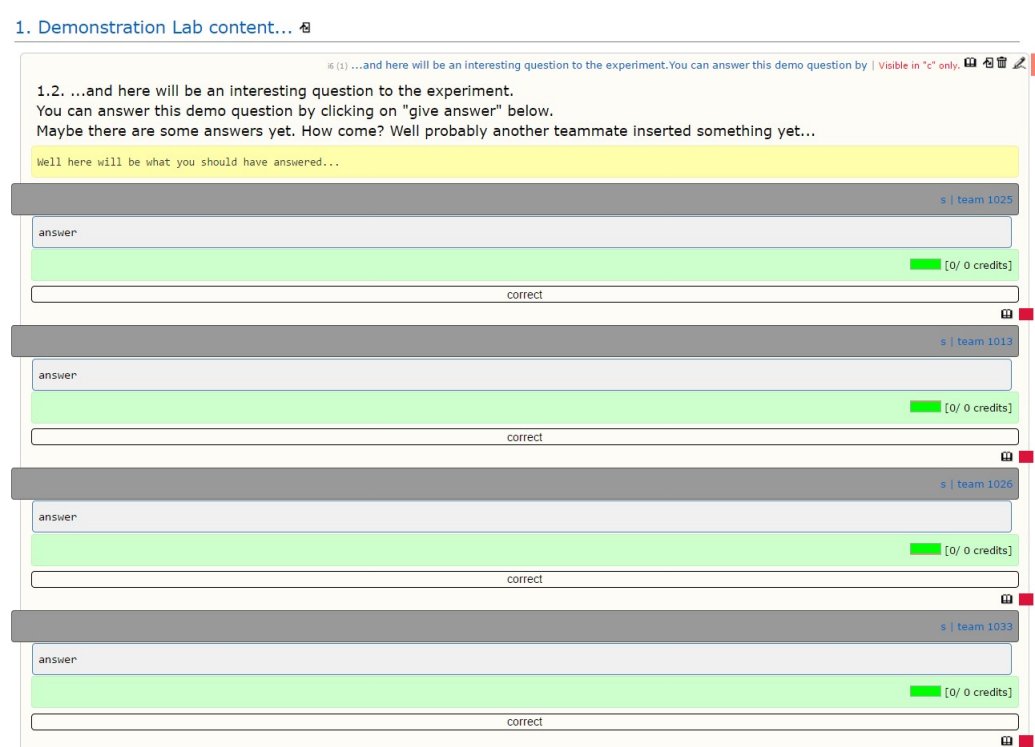


Figure 2.1: Cross-correction in the labsystem: [1]

There are also concepts, which can be used to edit and extend the existing functionality. For instance, HTML tidy and CSS tidy - for automatically formatting and correction HTML and CSS code. Tools like Prettyprint can be used to ease the visual perception of contents.

Taking under consideration the two TUM iLab courses as a concrete example of usage of the labsystem, we can see that it can also be combined with lectures (2.5a) and video recordings. They give students opportunity for face-to-face discussions, as well as for additional self-preparation.

When combined with suited hardware equipment (2.4b) for conduction of practical exercises - as done in the two ilabs - the labsystem helps to create an isolated lab environment (2.4a). This environment enables learners to not only observe, but also to work with different services. Conducting experiments in such environment creates additional opportunities for the students to come in contact with each other and to exchange knowledge and ideas. Communication between students is motivated and supported by giving them opportunity to form and work in teams.

2.2.2 Learning elements in the labsystem

This subsection goes into detail about statistics gathered by different elements of the platform and how they are used to give feedback to learners.

The kernel of the labsystem are its *learning elements*: **page**, **multiple choice**, **input**, **collection**, **lab** and **schedule**, shortly - **p**, **m**, **i**, **c**, **l**, **s**. Each one of the elements holds different information and helps to collect different data.

Each **p** element consists of different kinds of text - usually used for creating theory chapters and exercise instructions. Each **m** learning element consists of a multiple choice question, the answers to it, a vector with the bit mask of the correct answers and a section for an additional explanations to the answers. Each **i** element consists of a free input question, example solution and possible credit points. Each **c** element is an aggregation of other basic elements. Whereby, there is also a **C** element, which is an aggregation of **c** elements. An **I** element has all functionality needed by each learning element. It consists of a prelab, a lab and a correction - all elements belonging to one topic. It is usually time limited by a schedule. An **s** element has a start, end and a link to the **I** element which it puts time limitations on. [12]

For the purposes of this thesis most important are the **m**, **i** and **I** elements.

As first means for feedback (2.2b), the labsystem offers **multiple choice questions** (Figure 2.2), which are instantly corrected after submitting an answer. They allow students to master basic contents before moving to a more advanced level. Learners have three attempts to choose all correct answers (by checking a box). When not all of the correct answers have been chosen, the attempt is marked red. After finishing the third attempt or after all of the correct answers have been chosen, they are marked green and their type is enhanced. Wrong answers are marked red. Additional explanations and hints can be added on the bottom of these feedback elements. They give further information and deeper understanding of the answers.

The answers of each learner to the questions in the multiple choice elements are one kind of data that is being gathered. This data is being collected by the system in a permutation vector [12] and is made visible to the learner, the tutors and the authors. This is possible by setting the visibility rights of each element or for each individual accordingly.

Multiple choice questions are currently used for self-preparation by giving immediate feedback. We want to implement further supporting mechanisms, which visualize the collected data from those questions. Giving an overview of the statistics of all teams would allow tutors to identify tendencies and help students self-regulate their performance.

Reporting of the progress in the exercises to tutors occurs via **free text inputs** (Figure 2.3), which participants fill out while doing the exercises. This eliminates the need of extensive post factum reports.

Each **i** element collects the answers, the correction comments and the granted

1. Demonstration Prelab Content

1.3. This is a multiple choice question. Click on "give answers" to set the check marks. Don't forget to "save"...

This answer is **correct**.

This answer is **correct**.

This answer is wrong.

Here you might find some remarks why the solution is correct.

1.5. This is another multiple choice question. Now I don't give you the answers ;) When was the first web based internet lab held in Tübingen?

winter semester 2004/ 2005

winter semester 2005/ 2006

winter semester 2003/ 2004

summer semester 2005

summer semester 2004

Well the lab started in winter 2003/ 2004 based on a book of Jörg Liebehers. It was maintained by Uve Bilger then. In summer 2004 it got totally renewed by Marc-Oliver Pahl and Uve Bilger. The later prelabs were edited by Heiko Niedermayer. All was put on the predecessor of the system you are just using. The current system was introduced in summer 2005.

Figure 2.2: Multiple Choice questions in the labsystem: [1]

credit points for one free input question. It allows students to see specific explanations, suggestions and hints that tutors gave them for each question. This is a self-directed feedback, clarifying concretely what still needs to be improved.

Instructors see uncorrected answers in red. They can leave feedback to the students in a separate section to the answer of each question. In addition to that comments for other correctors can be provided in a hidden section. The correction and all comments can be saved and are not visible to the students until the check mark box in the right downside corner (Figure 2.1) of the question is checked. This box can also be directly checked without opening the question, as the value of the credits is set by default to the maximum possible.

The **i** elements can also be used to collect comments and criticism from students, as done in the ilabs. This allows their evaluations to be taken under account during the courses and to be used to dynamically improve different contents.

At any point students can see the status of the multiple choice questions and the graded exercises. They cannot directly finish the multiple choice attempts but they can manually "close" the lab tasks. After that they cannot answer anymore and the correction can start.

After their answers have been corrected, learners get a notification email and are able to see their performance statistics. This is made possible by the **I** element, which generates overview pages with all questions and gained credit points. Depending on the set visibility rights, a student, for example, is able to see the results of their team only, whereas a tutor is able to see the results of all teams.

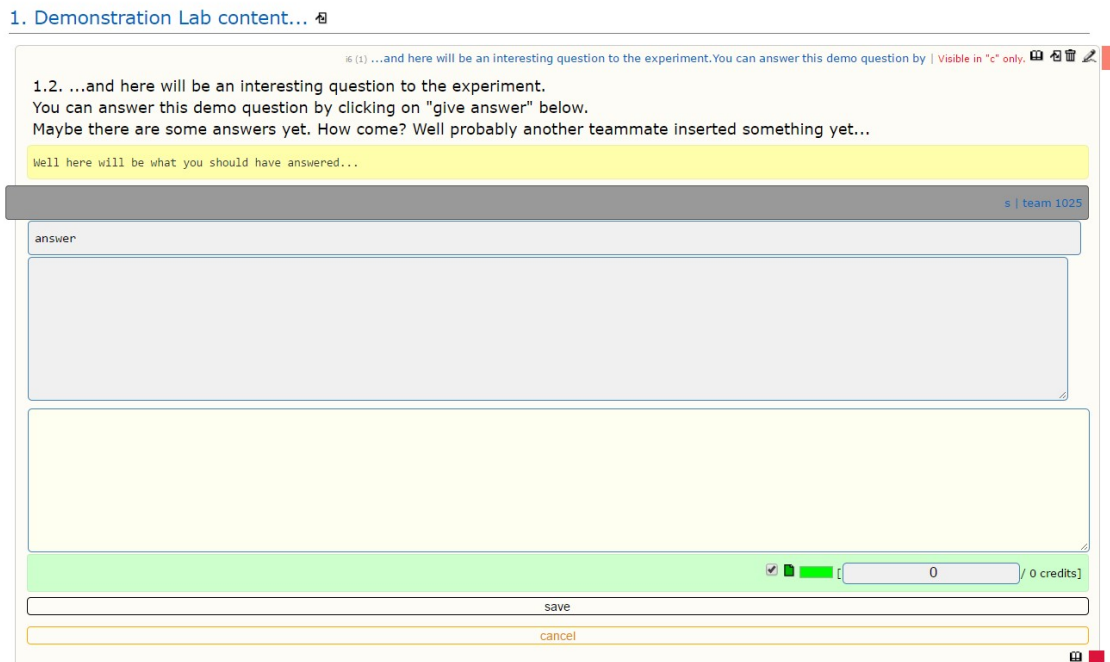


Figure 2.3: Free Input element in the labsystem: [1]

The overview page is called "my statistics" (Figure 2.4) and shows outcomes in



Figure 2.4: "My statistics" in the labsystem: [2]

percentage, as well as in a graphical representation. Each question is represented by a box. And each box is shaded with a color that varies from green to red depending on the grading.

The purpose of this visualization is to help students get a structured overview of their results and to be able to assess their development.

Additionally, learners have opportunity to give feedback and communicate problems at anytime directly through the system. A "send email" button, included in each element, directly links the element to an email body (Figure 2.5). It enables the interaction with advisers and tutors, as well as with other participants as it includes a list with all people the email could be sent to.

Here you can send mails...

The screenshot shows a web interface for sending emails. On the left, there are three sections: 'roundmail' with a 'check all/ uncheck all' link, 'supervisors', and 'users'. The 'users' section contains a list of 18 users, each with a checkbox and a unique identifier (name-XXXXXX, forename-XXXXXX) and a number in parentheses. On the right, the 'your mail' section contains a text area for the message body, a 'subject' field, and a 'send the mail...' button. Below the message field, there is a checkbox labeled 'Send me a report including the source of this mail.' and a 'send the mail...' button.

Figure 2.5: Email in the labsystem (without real names): [1]

2.2.3 Additional visualization feedback element in the labsystem

The above-discussed feedback elements exist since the initial creation of the labsystem. There is, however, one eLearning supporting statistic element (Figure 2.6) created post factum, in addition to them. It visualizes the aggregated distribution of credits for each input question (in one lab) in relation to the time spent (in hours and minutes).

The algorithm behind the graph works the following way. It retrieves all relevant events from the database log (such as login, logout, opening of an element, editing of element, etc.). It categorizes them according to the role of the person doing the action (student/corrector/viewer) and according to whether they represent an opening or a closing event. Then it goes through all events. When an opening occurs, it assumes that the participant is working on the according element. When a closing occurs, the algorithm stops the time tracking for the element. Important to mention is that the time tracking also stops after a timeout or when an opening of another element occurs. [2]

The algorithm then calculates a time span for each (m/i) question element, processed in a student role. This time span is the sum of all time intervals tracked from the opening of the question element until one of the following events: the closing of the element, the opening of another question element, timeout or logout. This means that time intervals spent e.g. for page elements in between are assumed to be preparation time needed to answer the according question. The time spent after answering the last question is not considered relevant. [2]

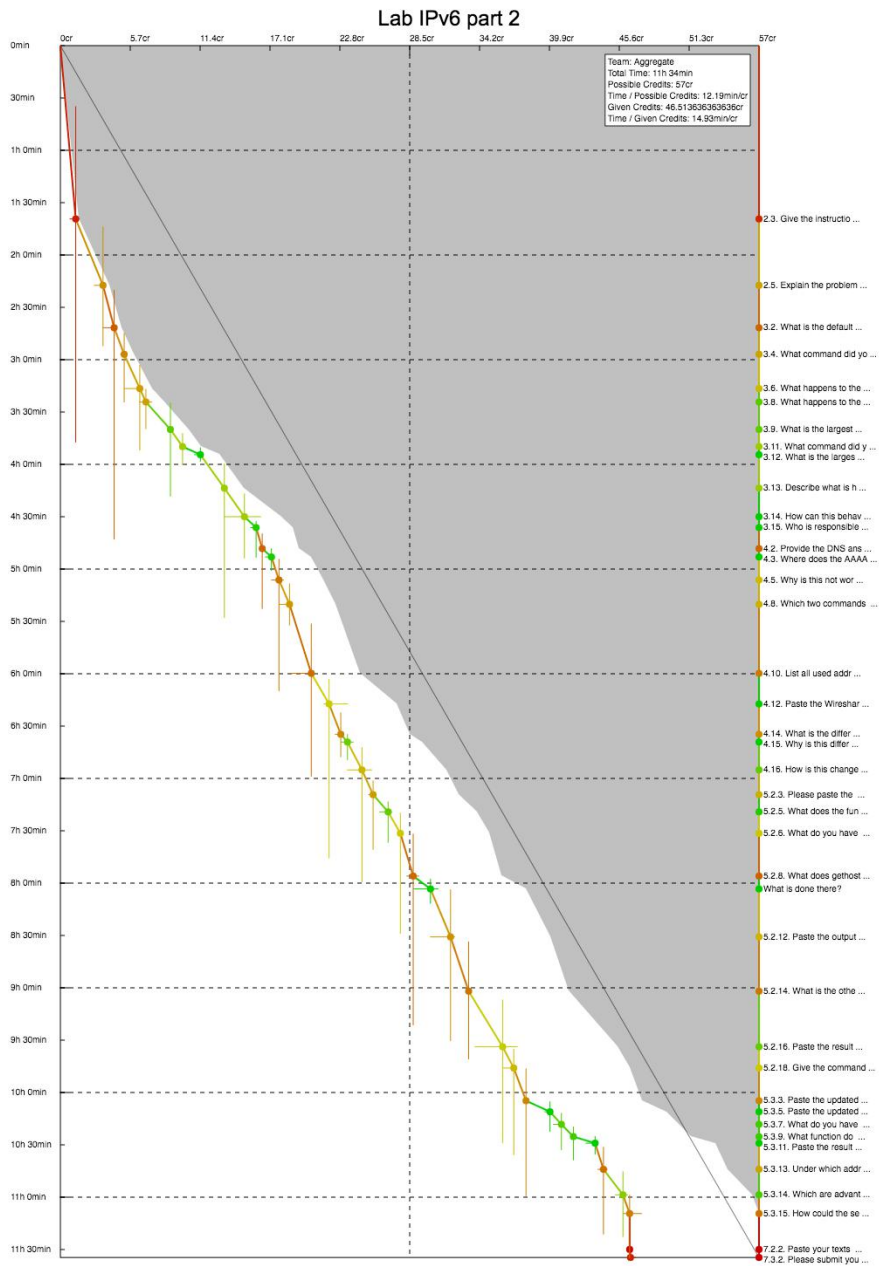


Figure 2.6: eLearning supporting statistic element in the labsystem: [3]

There are three lines to be considered in the graph. The first (the right most) line stands for the linear case when equal time is spent for each gained credit and all credits

are received. The second (middle) one considers again the case when the possible maximum of credits is reached, but for the time which teams actually spent for each question. And the third (left most) one represents the allocation of the aggregated number of credits teams gained (not the maximum) in relation to the actual time distribution.

This graphical representation aims to reveal anomalies to tutors. When the second line differs too much from the first one, this indicates problems. Tutors are able to recognize, for example, when teams need much more time for the completion of one question than expected and hereby they can adjust the question or grading accordingly. This aims to ultimately support learners by giving them good structured exercises and a fair grading system.

2.2.4 Our goals

The goal of this work is to develop additional eLearning supporting statistic elements which make further use of the existing algorithms and data gathered from the input and multiple choice elements.

The multiple choice data, for example, could help for improving the weekly preparation of the teams. Whereby, the input data could be used for giving an overview of the total time spent for one lab, including the correction period. This aims to also support the correctors by recognizing when a correction takes more time than foreseen.

2.2.5 Feedback elements' features

In this subsection we present an overview of the labsystem's features according to a taxonomy of features, which is introduced and reviewed in detail in subsection 2.5.1. This taxonomy is created on base of the elements present in the labsystem, as well as in the Coursera, edX and Moodle platform, which help to fulfill the requirements for a good learning process. The taxonomy helps to assess the existing feedback elements in the labsystem and to compare them with those of the other three platforms in section 3.4. It helps us to recognize if there are important features missing and to eventually give us ideas about what more can be implemented in the labsystem.

Description of table 2.1: The labsystem's feedback element *email* allows linking an element to an email body in the system itself (6.1b) and also displays a list of people who an email could be sent to (6.1c). There is no option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a). The labsystem does not have a *chat* or a *forum*.

³Shown in the statistics page

⁴Note: As soon as learners save their progress, it is visible to correctors. However, instructors do not grade exercises before the "lab is closed".

⁵Visible only for instructors.

⁶Can be seen in the schedule, but is not explicitly mentioned next to each question.

Feedback element	Fulfilled requirements	Unfulfilled requirements
Email	link element (6.1b), send to: list (6.1c)	specify organizations (6.1a)
Chat		no chat available
Forum		no forum available
Multiple Choice Questionnaire	score/max (6.4a), total score (6.4b ³), coloring (6.4e), explanation (6.4f), status (6.4g), multiple attempts (6.4h), used attempts (6.4i), enhance type (6.4n), multiple right answers (6.4o)	submission time (6.4c), check/X (6.4d), time left (6.4j), finish directly (6.4k), flag question (6.4l), certainty level (6.4m), dropdown field (6.4p)
Free input question	save progress (6.5a ⁴), color (6.5c ⁵), upload file (6.5d), history (6.5f), status correction (6.5g), score/max (6.5h), comments (6.5j)	status submission (6.5b), due date (6.5e ⁶), ranking (6.5i)
Graphical visualization of statistics	boxes (6.6a), color (6.6b), percentage (6.6c), time/-points (6.6d)	users/site (6.6e)

Table 2.1: Feedback element requirements in the labsystem

When it comes to the Multiple Choice Questions, the system offers different kinds of statistics. The relation between reached score and maximum score is shown (6.4a), as well as the total score (6.4b). Red/green coloring of wrong/right answers (6.4e), explanation to the given answers (6.4f), status of the grading (6.4g), a possibility for more than one attempt (6.4h) and for multiple right answers (6.4o) are also available. Furthermore, the number of used attempts are displayed (6.4i) and the type of the right answer(s) after grading is enhanced (6.4n).

Under the not included features there are check and X marks (6.4d) - as a way of marking right/wrong answers, time of submission (6.4c) (only visible to people with access to the database) and time left (6.4j). Moreover, there is no option to directly finish an attempt (6.4k), to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field (6.4p).

The open input fields allow saving progress before officially submitting it (6.5a). It is, however, visible to the tutors. Corrected/uncorrected items are colored accordingly (visible only to tutors) (6.5c). There is an option to upload files and to show history of changes (6.5d). The status of the correction is shown (6.5g), as well as the relation between reached score and the maximum score (6.5h). A hidden from the students comments section is available for the tutors (6.5j). The status of the submission is not explicitly pointed out (6.5b), it is recognized by the ability/disability to edit the field. Due

date can be seen in the schedule, but is not explicitly mentioned next to each question (6.5e). No ranking of the answers through voting is possible (6.5i).

The labsystem has a "my statistics" feature, which displays the progress of each participant/team. It contains graphical representations of the answers with boxes (6.6a), which are colored depending on the number of reached points (6.6b). Results are also shown in percentage (6.6c). There also exists a graph, which visualizes the time spent per gained point (6.6d). There is no graphical representation of the number of users or registrations per country/city/etc. (6.6e).

2.3 What is a good learning process and how to create it?

In order to implement eLearning mechanisms, which support a good learning process, we need to clarify what is considered to be a good learning process. More specifically, we need to examine which methods and elements ensure such process by an eLearning platform.

In subsection 2.3.1 is presented a summary of best practices and a summary of requirements for a good learning process, which are structured in a taxonomy. Throughout the text in this section the reader observes numbering (1.1 up to 1.6), which references to this taxonomy. The requirements, presented in the section, are concrete means used in the labsystem, Coursera, edX and Moodle platform to achieve the recognized best practices. They present example set of criteria, which can and should be extended when other systems are also taken under consideration.

According to John Hattie (2012) [13] the focus by most teaching practices falls more on "how to teach" than "how to learn". In order to support the learners, the education process needs to consider students' prior knowledge, what motivates them and how do they develop a deeper understanding of a topic. It needs to engage with students' initial understanding, to use different strategies for structuring and communicating new contents, so that as end result it can reduce the "gap between where the student 'is' and where he or she is meant to be" [13].

The goal of both traditional classroom and online education is to reduce this gap. However, for each environment specific requirements need to be considered. In order to optimally support the learning process, an eLearning environment, for instance, should be: simple, interactive, allowing collaboration, diverse and authentic. [11]

The simplicity condition (1.1) requires an eLearning environment to be straightforward and easy to understand and use. [11] When the system does not endorse focus on the content, the learner may get lost in organizational details. This could lead to frustration and demotivation. Simplicity could be achieved by providing an intuitive interface, as well as comprehensive documentation in form of video tutorials, help centers, blogs, etc. (2.1a, 2.1b) When the time spent and gained experience are optimized, the participants become more engaged in the learning process.

According to the theory of Constructivism [13], knowledge is a subjective self-construction. Every fact that a person perceives is a self-interpretation. Collaboration, in this context, gives learners opportunity to see different perspectives and to get a more extensive insight on the discussed topics. This deepens their understanding of the content and develops social and cooperative skills, such as critical thinking, negotiation and leadership [11]. For this reason an eLearning platform should be interactive (1.2). It should engage the learners by giving them opportunities for support and guidance. In order to achieve that, it should offer mechanisms for synchronous and asynchronous communication (2.2a).

Students learn more when they take part in discussions, give feedback (2.2b) and try to explain concepts which they learned to others. Research of "learning-by-doing" [14] as educational practice shows that students learn better when applying theoretical concepts they have just read about. Figuring out a solution, finding out how well it works, considering alternatives, trying again and seeing if the new solution works better creates a mind map. Students connect theory with emotions they experience while building the map. In this way, knowledge stays in their long-term memory. [15] This is why an education system should give learners opportunity to work on diverse problems (1.3), to try out solutions, to make mistakes and to learn from them. Mechanisms for self-preparation like multiple choice questionnaires, or mechanisms for giving and receiving feedback such as free input fields or graphs, contribute to that goal. (2.3a) Such methods for self-regulation, also help learners to prepare for graded tasks. Learners can master the concept and refine their answers before the grading. This reduces pressure and frustration caused by not being familiar with the expectations of the grading system.

An advantage of eLearning platforms in this context is that they are customizable artificial "playgrounds". They are isolated environments [11], where learners can safely conduct experiments. (2.4a) Those experiments contribute to the platform's authenticity. They allow learners to face relevant practical problems. Such problems help to "dissolve the artificial wall between the classroom and 'the real world' [11]. This means that learners can apply learned theory. This helps them to understand why the presented contents are important and to see how they can actually be used in practice.

eLearning environments can also be combined with isolated physical environments, which serve the purpose of the experiments, as done in the two ilab courses. (1.4) (2.4b) This further contributes to the goals of interactivity, diversity and authenticity. A disadvantage of the traditional classrooms is that they do not allow conducting some experiments. As their level of isolation is not as high, mistakes can cause extensive damage. Whereas, in specially created for such purposes laboratories, diverse problems can be recreated in a secure way. This gives learners security to involve themselves freely in the learning process.

Technology changes. With it the educational needs of the learners change as well. In order to fulfill those new needs, an eLearning platform should consider the

characteristics of its users [16] and those of the environment. It should adapt (1.5) to new pedagogical concepts, but also accustom good practices from traditional education [13]. For example, it could offer online courses which are combined with ongoing university study programs. (2.5a) Face-to-face discussions allow learners to feel more connected to the process, which increases their motivation.

It is inevitable for an eLearning platform to require and gather personal information of its users. Such data is used to contact learners, in order to provide them with feedback, results, to offer them personalized programs, to issue certificates for them, etc. As such data is sensitive, every platform should be respectful and protective of it (1.6). If a learner mistrusts the system, they will simply refuse to use it or will not dare to explore its full potential. Protection of personal information could be achieved through setting visibility rights or implementing Privacy Policies. (2.6a, 2.6b)

2.3.1 Summary: Best practices and requirements

Best practices for a good learning process:

1.1 *Simplicity* [11].

- (a) A good learning process is easy to understand and use.
- (b) It allows focus on the content, not organization.

1.2 *Interactivity* [11, 13].

- (a) It enables collaboration.
- (b) It provides different perspectives.
- (c) It teaches social and cooperative skills.

1.3 *Diversity* [14]

- (a) It uses diverse strategies to communicate new contents and to assess learners' progress.

1.4 *Authenticity* [11].

- (a) It allows learners to work on relevant for them problems.
- (b) It enables learning-by-doing.
- (c) It creates environment where learners can make mistakes and learn from them.

1.5 *Adaptivity* [13, 16].

- (a) It allows accustomization of good practices from traditional education.

1.6 *Privacy* [2].

- (a) It is respectful and protective of personal data.

Features helping to fulfill those best practices by eLearning platforms:

2.1 *Simplicity* (2.2)

- (a) The eLearning platform provides an intuitive interface.
- (b) It provides help and documentation.

2.2 *Interactivity* [11, 13]

- (a) It provides mechanisms for synchronous and asynchronous communication.
- (b) It provides feedback elements.

2.3 *Diversity* (2.2)

- (a) It provides diverse content structures, such as multiple choice questionnaires, free input fields, graphics, editors, etc.

2.4 *Authenticity* [11] (2.2)

- (a) It provides an isolated learning environment.
- (b) It is combined with a physical environment for conducting experiments.

2.5 *Adaptivity* [13]

- (a) It offers services combined with university study programs.

2.6 *Privacy* (2.2)

- (a) It follows Privacy Policies.
- (b) It allows setting visibility rights.

2.4 Feedback

All of the best practices and requirements from section 2.3 are interconnected and relevant for establishing a successful eLearning process.

As a most effective mechanism in any environment, however, is recognized feedback. In eLearning environments, in particular, feedback elements and statistics help for communicating feedback. Before we go into specifics about the elements, however, we first need to reason about the importance and role of this mechanism in general.

In subsection 2.4.1 we present a taxonomy of purposes and requirements of feedback. Throughout the text in this section the reader observes numbering (3.1 up to 4.4), which references to the taxonomy.

Feedback can be categorized into summative and formative. The first category aims to assess if learners have reached the goals set to them. The latter aims to provide

a detailed assessment of the students' performance, which shall help them reach the learning goals. [17] Feedback teaches learners how to self-regulate their performance (3.1b). It informs them about their strengths and weaknesses and educates how to address the weaknesses [18].

Summarative, or also external feedback, can be further divided into feedback based on motivational and on informative components. Informative based feedback notifies where a learner stands in reference to others, a certain criteria or their previous performance. Motivation-based feedback elaborates positive or negative reinforcement. Research shows that the absence of positive feedback is correlated to negative emotional outcomes, such as disappointment and frustration [19]. This leads to demotivation and disengagement from the learning process.

Feedback leads learners throughout the learning process by helping them answer three main questions: "Where am I going?", "How am I going there?" and "Where to next?" [13]. It can be seen as a correction guideline. It ensures that each student knows at each point what the goals of the learning process are. It clarifies the success criteria (3.1a). It creates a safe learning environment (3.2a), which motivates learners to go beyond their comfort zone by making mistakes and learning from them (3.2). It teaches students how to recognize what is the next step after having successfully finished a knowledge milestone.

The frequency with which feedback should be given differs (4.1). Research [13] shows that feedback should be reported more often to students, which struggle more with the material. Correspondingly - with a delay to more advanced students. In the first case feedback is meant to prevent learning wrong information and going further into an incorrect direction (3.3a). In the latter case the reasoning is such that enough time should be given to the students to develop and try out their own ideas, before providing them with an answer.

One recognized issue by giving feedback is that tutors and teachers often think only about how to deliver it and not about how it will be received. This could lead to different scenarios, all of which have unsatisfying outcomes. Students can misunderstand or not understand the feedback at all and simply disregard it. It could also be the case that they believe they understood it correctly, when they actually did not. As a result they are not be able to apply it to the process and advance further.

This is why feedback should also be asked from students. This is how a teacher could determine if the given feedback was received and if the teaching provoked the right learning process (3.3b).

Feedback needs to be well-reasoned and explained, so that learners consider the person giving it fair and trustworthy (4.2). However, too much feedback does not improve the understanding, just the opposite. It can overwhelm the receiver. (4.3)

Depending on the culture of the student, different kind of feedback should be considered (4.4). For instance, learners with collectivist culture [13] are more prone to accepting feedback directed to the whole collective. They, however, are more likely

to accept self-criticism for the benefit of the team. On the other hand, learners with individualistic culture [13] are in general more open to self-directed feedback. They tend to disregard global feedback, which does not seem meant for them individually. However, they also tend to disregard negative feedback, preserving their ego.

All of the above listed considerations allow us to draw the conclusion that it is important for each environment to include mechanisms for communicating feedback.

2.4.1 Summary: Purposes and requirements

Purposes of feedback:

3.1 Feedback leads learners through the learning process.

- (a) It clarifies the goals and success criteria of the learning process.
- (b) It teaches learners to self-regulate their performance.

3.2 It motivates learners to go beyond their comfort zone.

- (a) It creates a safe learning environment, where mistakes are not considered failures, but opportunities to learn.

3.3 It is a correction guideline.

- (a) It prevents learners from learning wrong information.
- (b) It allows teachers to see their mistakes and adapt the learning process.

Requirements for feedback:

4.1 It is given at the right time.

- (a) More often to students who struggle with the material.
- (b) With a delay to more advanced students.

4.2 It is well-reasoned and explained.

4.3 It does not overwhelm the receiver.

4.4 It considers the culture of the receiver.

- (a) By learners with collectivist culture - it is directed to the whole collective.
- (b) By learners with individualistic culture - it is self-directed.

2.5 Feedback elements

In general, the existing basic feedback mechanisms are: email, chat, forum, multiple choice question(naire)s, free input fields, peer assessments and graphs, which visualize different statistics [20]. There are also other mechanisms such as video and audio conferencing, live webcasting, wikis, blogs, etc. Taking under consideration the labsystem and the purposes of this thesis, in the first part of this section we review in detail the basic mechanisms - their purposes and possible feature-implementations which contribute to fulfilling these purposes. The second part of the section introduces the concept of learning analytics and focuses in more detail on the purposes and goals of statistical visualizations.

The implementation features, which we present throughout the section, are gathered from our observations of the labsystem, Coursera, edX and Moodle platform. They build an example implementation set (2.5.1), which can and should be extended, when other platforms are considered. This set we define in order to compare the four mentioned systems and their ways to create a good learning process. Most importantly, this set helps us to make conclusions about the state of the labsystem.

Emails and forums are tools for asynchronous communication. Whereby, emails are mostly used for 1:1 (number of participants on one side of the communication channel:number of participants on the other side of the communication channel) private communication, forums are mostly used for communicating information to all course participants. [20]

The implementations of all feedback elements should aim to ease the collaboration between learners and teachers, as we identified in 1.2. With **emails** this could be achieved by enabling a feature, which suggests a list of people to contact or which links a concrete element/question to the email body [2]. An option, which allows setting of preferences/rights, can be used to reduce unwanted messages and further contribute to the goal.

Forums enable communication, structured in threads. These threads can serve as help articles. They contribute to a simple and interactive exchange of knowledge (1.1, 1.2) by allowing discussions to be organized in categories, sorted by topic/date/votes, evaluated, followed or hidden for a certain group of users.

A feature contributing to a diverse (1.3) collaboration are chats. **Chats** are used for synchronous 1:1 and N:N discussions. [20] They allow participants to quickly communicate problems and answer each others' questions. They can be restricted to a certain group of people, so that not all participants in the course are notified about the discussion. Chats could allow an option for audio or video conversations.

However, those are not only feedback mechanisms, but also general communication instruments. Multiple choice questionnaires, open answer questions, peer assessments and graphical statistics representations, on the other hand, can be seen as specific feedback elements (5.1).

Feedback thrives in non-mastery environment. It is most useful when learners have not reached proficiency level. This is why it is important for students to not see making mistakes as failures. They should be encouraged to take all opportunities to learn without fear of embarrassment. Learners also most often see grading as the end of the learning process [13] and disregard the feedback accompanying it. This is why they should be given opportunities to check their knowledge before continuing to the tasks, which are being graded (5.2). Hereby, **multiple choice questions** are well suited for self-preparation. They are most often automated and can be used to deliver immediate summarative feedback [21].

Implementation features by **multiple choice questions**, which visualize correctness of an answer, can contribute to a faster memorization of contents [22]. Examples for such features are check or X marks, green/red coloring of the answer or enhancing the type of the right answer. An option for adding an additional explanation to the given answers provokes deeper understanding rather than simple memorizing of facts. Displaying relation between reached score and maximum score, total score of all questions and number of used attempts, or choosing a certainty level helps students to get an overview and better assess the achieved results. Giving a possibility for multiple attempts, for directly finishing an attempt, as well as for choosing an answer from a given list or flagging a question (and answering it at a later point) allows diversity and flexibility. It also reinforces mastery of concept [21]. An option for showing time left, time of submission and status of the correction can help for a better time-organization and be used for the implementation of statistics' visualizations.

Free input fields are used by questions with an open answer. Such questions require individual explanation from learners and manual correction by a tutor or instructor. The feedback here is self-directed and could be delivered with a delay. It is private and shown only to the learner/team of learners, who gave the answer.

The model of peer assessments is the same, whereby the only difference is that the correction is done by other learners. Peer assessments provide suggestions about possible solutions. They present personal strategies and methods of different learners for solving problems. (5.3) They showcase variations of a solution that could be easier to understand for the learners than the "example solution" created by the instructors.

Different options can be implemented here as well. The purpose of a number of them we already explained by the multiple choice questions - showing status of submission/correction, coloring of items, showing due date/time remaining, as well as showing relation between reached score and maximum score.

An option for saving progress before submitting it officially gives learners opportunity to work on an answer for a longer time and save it directly into the system. This contributes to a simple interactivity, as there is no fear of deleting progress unintentionally. Being able to upload files allows a brighter range of answer representations, such as pictures, diagrams, code, etc. Saving history of changes eases reversing changes. An option to rank answers enables a faster discovery of the answer giving best insight. An

option to leave comments could be especially useful for tutors, for example, when more than one correction is conducted.

Each system collects data. **Analyzing** and **visualizing** this **data** can contribute to different aspects. It can help to understand how users use the different platforms, which features they find most useful, which not. It can also help to find out how do learners learn difficult concepts best and to make conclusions about how could a system be improved.

Visualizing statistics to tutors and content administrators allows them to see, for example, which questions have lowest rate of right answers. Considering this, they can make conclusions about what should be changed/added/removed in order to make the content more understandable and engaging. This would be for the benefit of the students. Such statistics, however, could be used to support the instructors themselves. By visualizing how much time is spend for the correction of a certain exercise, for instance, the workload per instructor could be adjusted accordingly. (5.4)

As stated in the First International Conference on Learning Analytics and Knowledge, **learning analytics** include measurement, collection, analysis and reporting of data about a learning process for the purpose of understanding and improving it and the environment in which it occurs [23].

Learning analytics enable a more learner-centered teaching, driven by data. They can be used for improvement of pedagogical practices. They can help to evaluate and adjust the used learning strategies. The learning process of each learner can be monitored closely, which leads to a more accurate up-to-date follow up of each learner. Through that, behavioral patterns can be discovered and modelled. By identifying and evaluating indicators of performance, predictions about future performance can be made. Based on progression and attendance statistics, early signs to drop out can be recognized. [23]

Presenting such data to learners in a usable form - through **visualizations**, can be used to guide the process of self-reflection on a learner's progress. Students become more self-aware and learn how to self-regulate their performance. [23] Coloring, displaying results in percentage or in graphs, showing the distribution of credits per hour, visualizing average time spent per exercise are possible statistics visualizations, which contribute to that purpose.

2.5.1 Summary: Purposes and features

In the following subsection we present a summary of the main purposes of the basic feedback elements and of implementation features for these elements. Those features we researched and gathered beforehand from all four eLearning systems that we consider in this thesis - the labssystem (2.2 labssystem), Coursera, edX and Moodle (3 Related work). They are concrete implementations which contribute to fulfilling the abstract requirements for a good learning process (2.3.1) and feedback (2.4.1), which we reviewed earlier. For each feedback element we itemize a list of concrete features and what do

those features contribute to specifically. We use this in Chapter 3 to compare the four platforms. This helps us to make a conclusion about whether important features are missing in the labsystem and if we should consider adapting some of them.

Summary: Purposes of feedback elements:

5.1 Emails, Chats and Forums

- (a) To communicate problems with advisers and peers.

5.2 Multiple choice questions

- (a) For self-preparation, to check progress before doing graded tasks.

5.3 Peer assessments

- (a) To present variations of possible solutions and different personal strategies.

5.4 Graphs(statistics)

- (a) To ease the visual perception of contents and progress.

Features of feedback elements:

6.1 Email

- (a) Option for learners to specify if they want to receive emails from organizations that represent the course - allows learners to customize the communication, contributes to *Diversity*
- (b) Field linking the question/element to an email body in the system itself - helps to easily appoint somebody to a certain element in the system, eliminates the need for copying links manually and the use of external email services, contributes to *Simplicity*
- (c) List of people who the email could be sent to - eliminates the need for searching the email addresses of the courses participants, enables fast collaboration with a desired group of people, contributes to *Simplicity* and *Interactivity*

6.2 Chat

- (a) Option for audio chat - provides a way for non-written communication, contributes to *Interactivity*
- (b) Restrict chat to a certain group of users - enables collaboration with a desired group of people, contributes to *Simplicity* and *Interactivity*

6.3 Forum

- (a) Separation of posts in categories - creates structure, simplifies finding a desired topic, contributes to *Simplicity* and *Interactivity*

- (b) Option to sort posts by votes/date/etc - voting enables fast assessment mechanism, sorting simplifies searching through posts, contributes to *Simplicity*, *Diversity*
- (c) Option to follow posts/comments - allows learners to stay up to date with a discussion interesting to them, contributes to *Interactivity*
- (d) Option to start/to forbid starting a new thread from an already existing one - enables management of discussions, contributes to *Simplicity*

6.4 Multiple Choice/Quiz Questionnaire

- (a) Relation between reached score and maximum score shown - facilitates fast assessment of the achieved results, contributes to *Simplicity*
- (b) Total score of all questions shown - facilitates fast assessment of the overall results, contributes to *Simplicity*
- (c) Time of submission shown - helps time assessment
- (d) Check/X mark - facilitates fast visual assessment of achieved results, contributes to *Simplicity* and *Diversity*
- (e) Red/green coloring of wrong/right answers - same as above
- (f) Explanation to the given answers - allows reasoning about why is a certain answer correct/incorrect, helps for a better understanding of the course materials, contributes to *Authenticity*
- (g) Status of correction/grading - open/closed, graded/not graded - helps for task progress tracking, helps instructors to recognize if a task is ready for correction, helps learners to recognize when a task has been corrected, eliminates the need of instructors manually notifying learners about the correction progress, contributes to *Simplicity*
- (h) More than one attempt possible - allows learners to make mistakes and learn from them, contributes to *Authenticity*
- (i) Number of used attempts marked - helps learners to recognize how many attempts they have left, helps learners and instructors to assess performance on a task, contributes to *Diversity*
- (j) Time left shown - facilitates better time planning, contributes to *Interactivity* (as a feedback mechanism)
- (k) Option to directly finish attempt - allows learners to directly see the answer of a question and move on to the next one, saves time when learners are aware from the beginning that they cannot answer a question correctly, contributes to *Simplicity*

- (l) Option to flag the question - enables learners to skip a question and easily find it and go back to it later, contributes to *Simplicity*
- (m) Option to choose certainty level - helps learners to regulate their self-assessment, helps instructors to assess learners' self-assessment about the extend to which they believe they mastered the contents contributes to *Diversity*
- (n) Enhancement of the type of the right answer(s) after grading - helps the fast visual recognition of the right answers, especially useful when multiple answers are present, contributes to *Simplicity*
- (o) Multiple right answers possible - increases the difficulty of a question, helps to assess the learners' level of mastery better, contributes to *Diversity*
- (p) Choosing an answer from drop fields possible - contributes to a more compact design outlook, contributes to *Diversity*

6.5 Open text field/Peer Assessment

- (a) Option to save progress before submitting it - eliminates the need of an external editor and the fear of deleting progress, contributes to *Simplicity*
- (b) Status of submission - e.g. in progress/saved/submitted - helps learners to recognize if their changes have been saved, helps instructors to assess the time progress of a task, e.g. if it is ready for correction, contributes to *Simplicity*
- (c) Coloring of corrected/uncorrected items - facilitates fast recognition of the progress of the correction of a task, contributes to *Simplicity*
- (d) Option to upload files - facilitates the usage of different file (and answers) formats, contributes to *Interactivity* and *Diversity*
- (e) Due date, time remaining shown - helps for time planning, contributes to *Simplicity*
- (f) History of changes/submissions/Last modified - helps to follow progress in time, makes restoring an old version and comparing a new to an old version easier, contributes to *Simplicity*
- (g) Status of correction shown - helps for task progress tracking, helps learners to recognize when a task has been corrected, eliminates the need of instructors manually notifying learners about the correction progress, contributes to *Simplicity*
- (h) Relation Reached score/Maximum score shown - facilitates fast assessment of the achieved results, contributes to *Simplicity*

- (i) Ranking of the answers through voting possible - facilitates fast assessment of the answers, enables searching for the "best" answer according to votes number, contributes to *Diversity*
- (j) Comments section available - allows visible and hidden discussions, contributes to *Interactivity*

6.6 Graphical visualization of statistics

- (a) Graphical representation of the answers (e.g. with boxes) - combined with the next point, contributes to *Simplicity* and *Diversity*
- (b) Coloring of the answers (boxes), depending on the number of reached points - facilitates fast understanding and assessment of the reached results, contributes to *Simplicity* and *Diversity*
- (c) Results presented in percentage - allows precise assessment of the achieved results, contributes to *Simplicity*
- (d) Graphical representation of time spent per gained point - allows comparison of achieved results and desired results, contributes to *Diversity*
- (e) Graphical representation of number of registrations per country, users per site, etc. - helps instructors to assess the "success" of a course, helps content creators to improve and customize contents, contributes to *Diversity* and *Authenticity*

2.6 New Artifacts

In Chapter 2 we presented the Analysis part of the thesis. We chose to do so in a broad way, talking about principles and good practices valid for a good learning process in general. We did so in order to have a background and overall valid reasoning for our choice of artifacts to implement.

In 2.5.1 we considered concrete implementation features, which enable a successful learning process by the lab system, Coursera, edX and Moodle platform. At the end of Chapter 3 we use those features to compare the four elearning systems. This comparison aims to inspire concrete implementation ideas, which we have not thought of, but which can be helpful for reaching the goals of the thesis. Nevertheless, the broad analysis is still needed in order to have in general valid reasoning for our decisions, regardless if those decisions are to implement our own ideas or ideas that we adopt from other platforms.

In the following we present five artifacts ((I) - (V)) that we consider implementing and the reasoning behind them. They are our own ideas and are based purely on the pedagogical concepts we recognized as important in 1.6 and 3.3.

- (I) Graph depicting the whole lab process in time.
- (II) Visualization of the approximate time left until the end of the lab.
- (III) Visualization of worst answered MC and input questions.
- (IV) Visualization of additional multiple choice statistics - the absolute number of times each multiple choice answer has been chosen, as well as the distribution of 'clicks' for all answers in percentage.
- (V) Emotion/Like/Dislike feedback below each element.

The reasoning behind (I) is that we want to make the learning process more transparent and adaptive to the needs of all participants. Such visualization allows the recognition of time related issues regarding both completion and correction of each lab. It would give an overview of the course workload, so that different parts can be adapted accordingly.

(II) aims to increase the self-reflection of the learners. It aims to help them assess their performance. This can be used as a guideline and to reduce frustration. Participants will be able to recognize when they are spending too much time on a task and to better structure their time planning.

The goal of (III) and (IV) would be to help the recognition of tasks where learners achieved worst results - where they got least credits, needed most attempts to answer. Such visualizations will enable instructors to react to deficits before the end of the course, by emphasizing explicitly on the recognized problematic contents. The findings could also be used for adapting tasks after the course's end. Both artifacts aim to contribute to making the platform more interactive and engaging.

(V) can help to improve the emotional engagement of the participants in the course. Participants will be able to give emotional feedback and show which contents they find relevant. This can be used to improve the authenticity of the platform and to increase the interest of learners in the courses.

The following Chapter 3 discusses the features and purposes of the artifacts implemented by Coursera, edX and Moodle. At the end of the chapter we conclude if the artifacts that we listed above are optimal, if they should be adapted, or if other features would be more beneficial for the learning process of the ilab participants.

2.7 Summary

In the Analysis part of this thesis we introduced the lab system (2.2), which the thesis aims to improve. We presented the concept of eLearning (2.1), as well as best practices and requirements for a good learning process (2.3). We identified feedback as one of the most important factors, which contributes to such process (2.4). We discussed the purposes and requirements of feedback (2.4.1).

The ultimate goal of the thesis is to improve the learning process of the participants of the practical courses ilab1 and ilab2. This is why it was important for us to define evaluation criteria for the already existing learning process and features of the labssystem platform. It helped us to define the status quo. It also enabled us to backup with reasoning our own implementation ideas.

We, furthermore, reviewed in detail a set of basic feedback elements (2.5) and put together a taxonomy with implementation features for each element (2.5.1). We used this taxonomy to discuss the feedback elements in the labssystem and we use it again in the Related Work part of the thesis to discuss and compare the feedback elements of Coursera, edX and Moodle.

The requirements, together with the comparison of all four eLearning platforms in Chapter 3 help us to make conclusions about which elements are currently missing in the labssystem platform, but present in the other three. This shall enable us to assess if the design ideas, which we presented in 2.6, keep in line with the discussed good practices, if they should be adapted or if it is more advantageous to implement completely different artifacts.

From here we continue with the review and discussion of the Coursera, edX and Moodle platform. At the end of Chapter 3 we make a comparison assessment of all systems, including the labssystem, and present our conclusions.

Chapter 3

Related work: eLearning systems

In this chapter are examined three platforms for online education - Coursera, edX and Moodle. The chapter starts with an overview of each of the systems and then it goes into detail about their feedback elements.

At the beginning of each section is presented general information about the courses the platforms offer - number, subjects, etc. After that follow a detailed discussion about the feedback elements of each system and an examination of their Privacy Policies. This is necessary for clarifying what kind of data they gather, to whom they disclose it and with what purpose. This information is of interest for this thesis as it tells what statistics do the platforms offer. Then the concrete features of each feedback element are reviewed, using 2.5.1.

At the end of the chapter is given a structured overview comparison of the differences in all platforms, including the lab system, according to 2.5.1. This helps to make conclusions about the missing elements in the lab system and if the artifacts that were considered in 2.6 should be adapted, replaced or implemented in the way they were presented. The ultimate goal is to choose the feedback elements which are most suitable for the platform and from which the participants of the illab courses will benefit the most.

3.1 Coursera

3.1.1 General information

Coursera is one of the biggest interactive platforms offering online education, founded by Daphne Koller and Andrew Ng in 2012. It is venture-backed, for-profit and open for anyone. It partners with universities and other organizations (overall 149) from 29 countries and offers massive open online courses (MOOCs). [24]

At its start, Coursera was completely free of charge. It offered only courses in

Computer Science, Math and Engineering without giving any credit, but only a “statement of accomplishment” and a grade for a completed course. [25]

Nowadays it offers an optional Course Certificate as a formal recognition for one’s accomplishments and lectures in a substantial number of subjects, including Arts and Humanities, Business, Computer Science, Data Science, Life Sciences, Math and Logic Personal Development, Physical Science and Engineering, Social Sciences and Language Learning.

Coursera helps universities to combine traditional teaching methods with online education. This is why Blended learning (combination of face-to-face and online learning) is the last concept on their Key ideas list. For the business community Coursera offers “Curated Learning Programs”, “Progress tracking analytics” and “Seamless integration”, which are all special features for support of the specific needs of the companies. [24]

3.1.2 Learning process, its elements and statistics

The learning process of a Coursera learner includes video lectures, interactive quizzes, programming assignments and peer graded assessments.

The lecture segments are relatively short, which aims to keep students’ attention and focus during the whole lecture period [25]. The quizzes (Figure 3.1) are feedback means, contributing to one of the ideas with Key value to Coursera’s team, namely “Mastery Learning”. They try to ensure that the learners have fully mastered the content of a topic before they move to a more advanced lecture material. This goal is achieved by giving immediate feedback when understanding problems occur and by providing “randomized versions of an assignment” [24], so that the misconceived material can be reviewed until fully understood.

After submitting a quiz, learners can see date of submission and total score above all questions. They can also observe the correction of each question and explanation next to each correct answer. In case the given answer was wrong, learners are able to try answering again or skip the question. Depending on the specific course, up to ten attempts are possible.

There are also “in-video” quizzes during some video lectures. The results from these tasks are not saved for the user to see again later. Programming assignments are also corrected automatically. The number of submissions is unlimited.

Another key feedback feature of Coursera’s teaching are the Peer assessments. There are different kinds of assignments through out the different courses. Some of them, such as multiple-choice questions and mathematics problems, allow correction by a computer. Others, such as essays, videos and drawings, however, require human precision. This is why learners are motivated to review and critically comment each other’s work. [24, 26]

There are 5 steps that a learner can go through by peer assessments. The first

Feedback — XVIII. Application: Photo OCR

[Help](#)

You submitted this quiz on **Mon 26 May 2014 10:35 AM IST**. You got a score of **5.00** out of **5.00**.

Question 1

Suppose you are running a sliding window detector to find text in images. Your input images are 1000x1000 pixels. You will run your sliding windows detector at two scales, 10x10 and 20x20 (i.e., you will run your classifier on lots of 10x10 patches to decide if they contain text or not; and also on lots of 20x20 patches), and you will "step" your detector by 2 pixels each time. About how many times will you end up running your classifier on a single 1000x1000 test set image?

Your Answer	Score	Explanation
<input checked="" type="radio"/> 500,000	<input checked="" type="checkbox"/> 1.00	With a stride of 2, you will run your classifier approximately 500 times for each dimension. Since you run the classifier twice (at two scales), you will run it $2 * 500 * 500 = 500,000$ times.
<input type="radio"/> 1,000,000		
<input type="radio"/> 100,000		
<input type="radio"/> 250,000		
Total	1.00 / 1.00	

Figure 3.1: Coursera Quiz question: [4]

one includes doing an assessment themselves. Second (optional) one - doing a peer assessment training. By the second step the learner can practice evaluating three to five submissions that have already been graded by an instructor. The third step is to evaluate actual peers' assignments. The fourth (optional) one is to evaluate oneself. The fifth one shows the result. It is calculated from the own grade and the grades other learners gave to the corrector.

Further means of (feedback) communication are: Online forums: where questions between students and instructors are to be asked and answered, Support forums, Help Center (Figure 3.2), Coursera's Blog, as well as the big social networks: Facebook, LinkedIn, Twitter, Google+ and Tech Blog.

A special feature by the forums are the four forum icons: "pinned", "unresolved", "approved by instructor" and "instructor reply in thread". They can be used by instructors and students to categorize different discussions.

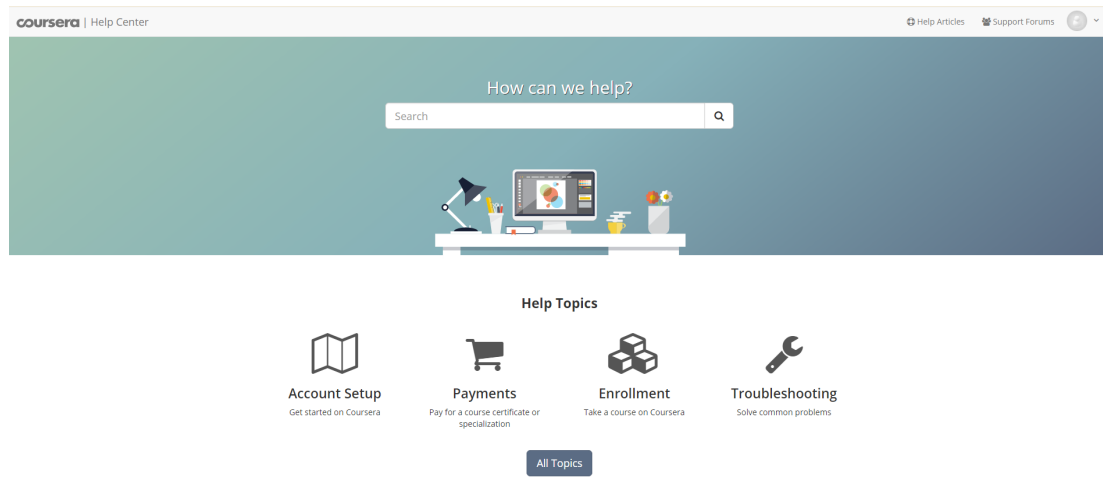


Figure 3.2: Coursera Help Center [5]

The privacy policies of Coursera explicitly state the distinction between Coursera's usage of Personal and Non-Personal Information, as for some of the available features no disclosure of Personal Information is necessary, whereas for others, related to the Online Courses, it is obligatory. [24]

As Non-Personal Information is considered any information that does not allow profiling and matching content to an individual. The gathered Non-Personal data includes which pages of the Site were visited, in what order, when, which hyperlinks were "clicked", sometimes IP addresses, operation system and browser software used by the user of the website, furthermore, cookies and web beacons. This information is used to track a person's related activity on the Site, to identify repeat visitors, time range spent on particular contents, areas of interest on the Site, etc. Based on this information, the Coursera team can, for example, suggest specific courses that could be of interest to the user, and by doing so to "personalize" [24] their experience. The gathered Non-Personal statistics are, moreover, used to analyze the collective behavior of the users and hereby to make conclusions about the usage of the different services on the Site, so that they could be improved accordingly. [24]

As Personal Information is recognized any information that can be used to identify an individual, such as name and email address. Such information is collected mainly for the means of feedback communication - in order to respond to questions, to send required updates, services or a specific course that the user requested. But it is also

used to track the progress, as well the number of students attending and completing an Online Course. [24]

The Coursera team asserts to use “industry standard physical, technical and administrative security measures” to protect the Personal Information of its users and to not disclosure it to Third parties except for special cases, such as a physical threat to a user or others or for the purposes of "research related to online education" [24]. The second case concerns sharing general information, such as quiz and assignment submissions, grades and forum discussions, with business partners, such as universities organizing the courses.

3.1.3 Feedback elements' features

Feedback element	Fulfilled requirements	Unfulfilled requirements
Email		specify organizations (6.1a), link element (6.1b), send to: list (6.1c)
Chat		no chat available
Forum	categories (6.3a), sort by (6.3b), follow (6.3c), restrict (6.3d)	
Quiz	score/max (6.4a), total score (6.4b), submission time (6.4c), check/X (6.4d), explanation (6.4f), multiple attempts (6.4h), finish directly (6.4k), multiple right answers (6.4o)	color (6.4e), status (6.4g), time left (6.4j), used attempts (6.4i), flag question (6.4l), certainty level (6.4m), enhance type (6.4n), dropdown field (6.4p)
Peer Assessment	status submission (6.5b), upload file (6.5d), history (6.5f), status correction (6.5g), score/max (6.5h), ranking (6.5i), comments (6.5j)	save progress (6.5a), color (6.5c), due date (6.5e)
Graphical visualization of statistics		boxes (6.6a), color (6.6b), percentage (6.6c), time/point (6.6d), users/site (6.6e)

Table 3.1: Feedback element requirements by Coursera

Description of table 3.1: Coursera’s feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c). There is no option available for learners to specify if they want to receive emails from organizations that represent the

courses (6.1a).

The platform does not have a Chat. However, a Forum is present. Posts are separated in categories (6.3a). They can be sorted by votes/date/etc (6.3b). They can be followed (6.3c) or restricted to a certain group of users (6.3d).

When it comes to the Quizzes, the system offers different kinds of statistics. The relation between reached score and maximum score is shown (6.4a). Total score (6.4b), time of submission (6.4c), check/X marks (6.4d) and explanation to the given answers are also present (6.4f). Furthermore, there is a possibility to take a quiz multiple times (6.4h) and to directly finish an attempt (6.4k). The number of attempts is marked (6.4i). A question could have multiple right answers (6.4o).

Under the not included features is red/green coloring of wrong/right answers (6.4e). Status of the grading (6.4g) and time left (6.4j) are not shown. The type of the right answer(s) after grading is not enhanced (6.4n). There is no option to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field (6.4p).

The open input fields do not allow saving progress before officially submitting it (6.5a). Corrected/uncorrected items are not colored (6.5c). Due date and remaining time (6.5e) are not shown.

There is an option to upload files (6.5d) and to show history of changes (6.5f). The status of the correction is shown (6.5g), as well as the relation between reached score and the maximum score (6.5h). A comments section is available (6.5j). The status of the submission is explicitly pointed out (6.5b). Ranking of the answers is possible (6.5i).

Coursera uses the gathered statistics, described in its Privacy Policy, for internal use. No graphical visualizations are placed at learners' disposal.

3.2 edX

3.2.1 General information

edX is a joint venture of Harvard University and Massachusetts Institute of Technology, founded in 2012. Similarly to Coursera, it is one of the big MOOC providers, aiming to provide unlimited by location and time constraints high education to people all over the world and also to combine traditional and new eLearning good practises. [27]

What differentiates edX from Coursera, however, is that it is a nonprofit and open source project. Moreover, the edX team explicitly states as one of its main goals the advanced research of online learning. This research explores questions about the motivation of the learners, the ways they master different contents and respond to specific assignments, and uses the statistics to develop best practices to improve the courses' outcomes. [27] This is also the ultimate goal of this work.

In the edX catalogue there are more than 2300 Courses, categorised by Subject (950+). In comparison to Coursera, the subscribers are also able to choose between

three Programs. For the completion of each program they can earn different certificates, namely: a “MicroMasters Certificate”, a “Professional Certificate”, or an “XSeries Certificate”. [27]

This more detailed program division gives the learners opportunity to put more focus on their exact specialization area and to get an acknowledgement which their professional position requires.

The essence of edX is, however, the free open source course management system Open edX, which allows developers to contribute new features to the platform and consists of the following six tools.

Open edX Studio, which instructors can use to expand the platform by creating their own courses. It allows them to add different contents to a course, to manage resources, schedules, grades and participants. It does not require the installation of any additional software and can be accessed directly through the browser, exactly as the second tool, namely the Open edX Learning Management System.

This tool is intended mainly for the learners. With it they can access the course content and take part in discussion forums and wikis. But it also provides an Instructor Dashboard for the advisers to enroll learners, publish reports and manage the courses which are already in process.

Two further features of the platform are Open edX are the "capa_module XBlock" and the "ORA2 XBlock". Whereby an XBlock is an architecture, which can organize different course elements into coherent components. For example, one component could be a single task or a text string. However, the elements and components can also be grouped into bigger blocks, such as lessons or even complete courses, and also deployed in any other instance of the system. [28]

3.2.2 Learning process, its elements and statistics

Similarly to Coursera, edX offers as feedback elements not only a Discussion forum and a Blog, but also Quizzes, Multiple choice questions, Numerical and Text input questions, Checkbox and Dropdown Questions, Poll and Survey tools, as well as Peer Assessments.

edX free input questions (Figure 3.3) expect an answer with a specific syntax (numbers/letters/special characters), which matches exactly the solution given by the instructors. They are corrected automatically. The allowed number of attempts can be specified. After submitting the right answer or third attempt, the right answer is marked and an explanation to it is shown.

Multiple choice questions in edX expect only one right answer. Right and wrong answers are marked with green and red color, as well as with check/x marks. An explanation can be observed next to the right answer.

Checkbox problems (Figure 3.4) are constructed exactly like multiple choice questions. The only difference is that the number of correct answers could be greater than one. Both types of questions are used for self-assessment, but also as graded tasks.

Text Input
1/1 point (graded)

What was the first post-secondary school in China to allow both male and female students?
Answer with a name from the modern period.

✓

Answer: Nanjing University or National Central University or Nanjing Higher Normal Institute or Nanking University

Explanation
Nanjing University first admitted female students in 1920.

You have used 1 of 3 attempts

✓ Correct (1/1 point)

Figure 3.3: edX Text Input Question: [6]

Dropdown questions (Figure 3.6) present a different visualization of multiple

Checkboxes
1 point possible (graded)

Learning about the benefits of preventative health care can be particularly difficult.
Check all of the options below that might be reasons why.

A large amount of time passes between undertaking a preventative measure and seeing the result. ✓

Non-immunized people will always fall sick.

If other people are immunized, fewer people will fall sick regardless of a particular individual's choice to get immunized or not. ✓

Trust in health care professionals and government officials is fragile. ✓

✗

Explanation
People who are not immunized against a disease might still not fall sick from the disease. If someone is trying to learn whether or not preventative measures against the disease have any impact, he or she might see these people and conclude (since they have remained healthy despite not being immunized) that immunizations have no effect.

You have used 5 of 5 attempts

✗ Incorrect (0/1 point)

Figure 3.4: edX Checkbox Question: [6]

choice questions. The difference is that they allow students to choose the right answer

from a dropdown list. The implementation of those questions includes status of correction, check marks and reached number of points in comparison to the total amount that is possible to reach.



Figure 3.5: edX Peer Assessment: [6]

A distinctive feature by edX peer assessments is that authors can include a Top Responses section (Figure 3.5). In this section learners can see all best graded responses and better assess their own answers. This also allows learners to find fast the best answers to a question that they are interested in.

A special feature is also that learners can save the progress of their response before submitting it. This eliminates the need for a separate editor, allows learners to execute all tasks entirely on the platform and simplifies the workflow.

Dropdown
1/3 points (graded)

What type of data is age?

Nominal ❌

What type of data is age, when rounded to the nearest year?

Discrete ✅

What type of data is life stage, such as infant, child, or adult?

Continuous ❌

Submit

You have used 1 of 5 attempts

🌟 Partially correct (1/3 points)

Figure 3.6: edX Dropdown Question: [6]

Poll (Figure 3.7) and Survey tools are usually used to gather feedback and opinions from the learners. They indicate chosen answers in percentage. As mentioned in 2.4, feedback should also be asked of from students. Those tools are examples of how this can be done, in a way other than with free input fields.

POLL
What is your favorite color?

<input type="radio"/> Red	50%
<input checked="" type="radio"/> Green	50%
<input type="radio"/> Blue	0%
<input type="radio"/> Other	0%

Submit

Results gathered from 2 respondents.

Figure 3.7: edX Poll Tool: [6]

According to its Privacy Policy, the edX team uses “commercially reasonable efforts to keep your Personal Information secure” and protects education records “by the Family Educational Rights and Privacy Act (“FERPA”) to the extent FERPA applies”. [27]

Similarly to Coursera’s Privacy Policy, a differentiation is made between Personal and Non-personal Information. Whereby the Policy states to use a security program

to protect its users' Personal Information. The defined purposes, which edX uses the gathered information for, overlap with those of Coursera.

What differs is that the Privacy Policy includes a much more extensive list of cases when Information (both Personal and Non-Personal) can be revealed to Third Parties. Whereby, the Third Parties, which the information is shared with, are called the Members - "educational institutions and other leading global members that provide courses through edX" [27]. Some of those cases are, for example, processing of purchases and transactions from Third parties, scientific research in the field of cognitive science and education led by Third parties, building connection between users with the same interests, responding to legal issues such as court orders, etc. [27]

3.2.3 Feedback elements' features

Feedback element	Fulfilled requirements	Unfulfilled requirements
Email	specify organizations (6.1a)	link element (6.1b), send to: list (6.1c)
Chat		no chat available
Forum	categories (6.3a), follow (6.3c), restrict (6.3d)	sort by (6.3b)
Multiple Choice Questionnaire	score/max (6.4a), total score (6.4b), check/X (6.4d), color (6.4e), explanation (6.4f), multiple attempts (6.4h), used attempts (6.4i)	submission time (6.4c), status (6.4g), time left (6.4j), finish directly (6.4k), flag question (6.4l), certainty level (6.4m), enhance type (6.4n), multiple right answers (6.4o), dropdown field (6.4p)
Peer Assessment	save progress (6.5a), status submission (6.5b), upload file (6.5d), history (6.5f), status correction (6.5g), score/-max (6.5h), ranking (6.5i), comments (6.5j)	color (6.5c), due date (6.5e)
Graphical visualization of statistics		boxes (6.6a), color (6.6b), percentage (6.6c), time/point (6.6d), users/site (6.6e)

Table 3.2: Feedback element requirements by edX

Description of table 3.2: edX's feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c). But there is an option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a).

The platform does not have a Chat. However, a Forum is present. Posts are separated in categories (6.3a). They can be followed (6.3c) or restricted to a certain group of users (6.3d). They cannot be sorted by votes/date/etc. (6.3b)

When it comes to the Multiple Choice Questionnaires, the system offers different kinds of statistics. The relation between reached score and maximum score is shown (6.4a). Total score (6.4b), time of submission (6.4c), check/X marks (6.4d), red/green coloring of wrong/right answers (6.4e) and explanation to the given answers (6.4f) are also present. Furthermore, there is a possibility to take a quiz multiple times and to directly finish an attempt (6.4k). The number of attempts is marked (6.4i). Each question has one right answer (6.4h). Status of the grading (6.4g) and time left (6.4j) are not shown. The type of the right answer(s) after grading is not enhanced (6.4n). There is no option to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field (6.4p).

In open input fields corrected/uncorrected items are not colored (6.5c) and due date and remaining time are not shown (6.5e).

There is an option to save progress before officially submitting it (6.5a), to upload files (6.5d) and to show history of changes (6.5f). The status of the correction is shown (6.5g), as well as the relation between reached score and the maximum score (6.5h). A comments section is available (6.5j). The status of the submission is explicitly pointed out (6.5b). Ranking of the answers is possible (6.5i).

edX uses the gathered statistics, described in its Privacy Policy, for internal use. No graphical visualizations are placed at learners' disposal.

3.3 Moodle

3.3.1 General information

Moodle (acronym for *Modular Object-Oriented Dynamic Learning Environment*) is an eLearning course management platform build on the Moodle project of the Australian company Moodle HQ. With 70 000+ registered sites, 90 000+ users and 10 000+ courses it is the most widespread eLearning platform. It is used by academia (universities, schools) and enterprise (government departments, healthcare organisations, airlines, etc.) for the management of both blended and completely online courses. [29]

The Moodle software is free and open source and has a translation in more than 120 languages. It can be hosted on one's own webserver and used for the creation of a personalized eLearning environment. Furthermore, on the website developers with desire to contribute to the Moodle project, can find the so called Developer Documentation. It contains detailed information about releases, development processes, developer meetings, working groups, forum discussions, guidelines, tools, plugins, etc.

3.3.2 Learning process, its elements and statistics

Moodle enables an intuitive learning process by offering a simple interface, text and equation editor (Figure 3.8), as well as drag-and-drop features. They allow easy transfer of files from cloud storage services, such as Dropbox and Google Drive, etc.

Diversity and interactivity are achieved by placing different features and feed-

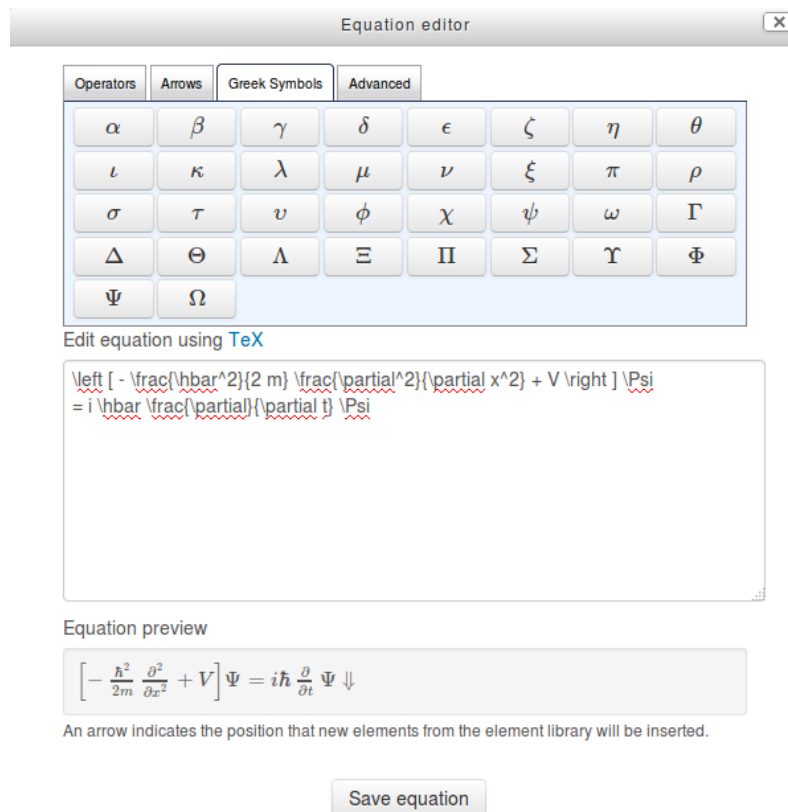


Figure 3.8: Moodle Equation Editor: [7]

back elements at learners' and authors' disposal. Moodle calls them activities. Teachers, for example, can set different quizzes, questions with specified answers, as well as free peer assignments and grade them with the help of the Quiz (Figure 3.9), Choice, Assignments and Workshop activity. Those activities allow navigating through questions, directly finishing attempts without specifying answers, marking questions with a flag (in order e.g. to answer later) and specifying a level of certainty.

Teachers can also build and deliver content, as well as enable interaction with LTI resources on other web sites through the Lesson and (LTI) External tool. Using the Database, Glossary and Wiki feature, participants can maintain records, definitions and

websites.

Synchronous and asynchronous communication, as well as feedback are further enabled through the usage of a Chat, Forum, Blogs, Feedback and Survey activity. All resources are well documented in a number of guides.

Moodle History Quiz

QUIZ NAVIGATION
 Not yet answered
 1 2 3 4 5
 6 7
 Finish attempt ...
 Time left 0:08:38

NAVIGATION

ADMINISTRATION

Question 1
 Not yet answered
 Base mark: 1.00
 Flag question

Why is the 20th August an important date? (You may choose more than one answer.)

Select one or more:

- a. It is World Mosquito Day
- b. It is the birthday of the founder of Moodle, Martin Dougiamas.
- c. It is the date of the first official release of Moodle in 2002.

Certainty ⓘ: C=1 (Unsure: <67%) C=2 (Mid: >67%) C=3 (Quite sure: >80%)

Question 2
 Not yet answered
 Base mark: 1.00
 Flag question

Match the cool Moodle features with the version in which they first appeared:

Groupings

Repositories

Drag and drop files

Certainty ⓘ: C=1 (Unsure: <67%) C=2 (Mid: >67%) C=3 (Quite sure: >80%)

Figure 3.9: Moodle Quiz: [7]

Moodle collects data only from sites, registered by their administrators with a valid URL and email address. It uses a check program with a number of defined evaluation rules on each site every week in order to identify all Moodle releases. [29] Every outdated information is excluded of their statistics.

In the Privacy Policy is stated that Personal Information is not shared or distributed, but could be accessed by individuals who administer the site and infrastructure, as well as by legal authorities. All information disclosed in the public parts of the sites is considered public and made available under the GNU Public License. [29] Non-Personal Information is collected for the purpose of site traffic analytics. Statistics, such as Top 10 countries by registrations (Figure 3.10), Moodle users per site comparison, versions used, can be reviewed on Moodle's website.



Figure 3.10: Moodle Statistics: [8]

3.3.3 Feedback elements' features

Description of table 3.3: Moodle's feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c). There is no option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a).

The platform offers a normal and audio Chat (6.2a). There is a possibility to

⁷Could be given.

⁸If specified.

Feedback element	Fulfilled requirements	Unfulfilled requirements
Email		specify organizations (6.1a), link element (6.1b), send to: list (6.1c)
Chat	audio (6.2a), restrict (6.2b)	
Forum	categories (6.3a), sort by (6.3b), follow (6.3c), restrict (6.3d)	
Quiz	score/max (6.4a), total score (6.4b), check/X (6.4d), color (6.4e), explanation (6.4f ⁷), multiple attempts (6.4h ⁸), time left (6.4j), finish directly (6.4k), flag question (6.4l), certainty level (6.4m), multiple right answers (6.4o), dropdown field (6.4p)	submission time (6.4c), used attempts (6.4i), status (6.4g), enhance type (6.4n)
Open input question	status submission (6.5b), upload file (6.5d), due date (6.5e), history (6.5f), status correction (6.5g), score/max (6.5h), comments (6.5j)	save progress (6.5a), color (6.5c), ranking (6.5i)
Graphical visualization of statistics	users/site (6.6e)	boxes (6.6a), color (6.6b), percentage (6.6c), time/point (6.6d)

Table 3.3: Feedback element requirements by Moodle

restrict the chat to a certain group of users (6.2b). A Forum is also present. Posts are separated in categories (6.3a). They can, for example, be sorted by votes or date (6.3b). They can also be followed or restricted to a certain group of users (6.3d).

When it comes to the Quizzes, the system offers different kinds of statistics. The relation between reached score and maximum score is shown (6.4a). Total score (6.4b), check/X marks (6.4d), red/green coloring of wrong/right answers (6.4e) and explanation to the given answers (6.4f) are also present. There is a possibility to take a quiz multiple times (6.4h) and to directly finish an attempt (6.4k). Each question can have multiple right answers (6.4o). Time left is shown (6.4j). There is also option to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a dropdown field (6.4p).

Time of submission (6.4j), number of used attempts (6.4i), status of correction/-grading (6.4g) are not shown. The type of the right answer(s) after grading is not enhanced (6.4n).

In open input fields there is no option to save progress before officially submitting it (6.5a). Corrected/uncorrected items are not colored (6.5c) and due date and remaining time (6.5e) are not shown. No ranking through voting (6.5i) is available.

There is an option to upload files (6.5d) and to show history of changes (6.5f). The relation between reached score and the maximum score (6.5h) is shown. A comments section is available (6.5j). The status of the submission (6.5b) is explicitly pointed out. Ranking of the answers is possible (6.5h).

Moodle uses gathered statistics for internal use. But it also places at learners' disposal graphical representation of number of registrations per country, users per site, etc.

3.4 Summary - Comparison

In this subsection we will present in a table format a structured comparison of the reviewed platforms according to the features, which we listed in 2.5.1. We only focus on the unfulfilled requirements. We also list additional elements, which the different platforms offer in order to make a complete assessment of the labsystem.

	Functionality
labsystem	eLearning platform for course and content management
Coursera	eLearning platform; for-profit MOOC provider
edX	free open source eLearning course management system; non-profit MOOC provider
Moodle	eLearning course management platform

Table 3.4: Functionality

Description of table 3.5: In the labsystem's feedback element Email there is no option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a). The labsystem does not have a Chat and a Forum.

Under the not included features in the Multiple Choice Questionnaires there are check and X marks (6.4d), time of submission (6.4c) and time left (6.4j). Moreover, there is no option to directly finish an attempt (6.4k), to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field 6.4p).

	labsystem	Coursera	edX	Moodle
Email	specify organizations (6.1a)	specify organizations (6.1a), link element (6.1b), send to: list (6.1c)	link element (6.1b), send to: list (6.1c)	specify organizations (6.1a), link element (6.1b), send to: list (6.1c)
Chat	no chat	no chat	no chat	
Forum	no forum		sort by (6.3b)	
Multiple Choice Questions and Quizzes	submission time (6.4c), check/X (6.4d), time left (6.4j), finish directly (6.4k), flag question (6.4l), certainty level (6.4m), drop-down field (6.4p)	color (6.4e), correction status (6.4g), time left (6.4j), used attempts (6.4i), flag question (6.4l), certainty level (6.4m), enhance type (6.4n), drop-down field (6.4p)	submission time (6.4c), status correction (6.4g), time left (6.4j), finish directly (6.4k), flag question (6.4l), certainty level (6.4m), enhance type (6.4n), multiple right answers (6.4o), dropdown field (6.4p)	submission time (6.4c), used attempts (6.4i), status correction (6.4g), enhance type (6.4n)
Open input questions and Peer Assessments	status submission (6.5b), due date (6.5e), ranking (6.5i)	color (6.5c), due date (6.5e)	color (6.5c), due date (6.5e)	save progress (6.5a), color (6.5c), ranking (6.5i)
Graphical visualization of statistics	users/site (6.6e)	boxes (6.6a), color (6.6b), percentage (6.6c), time/-point (6.6d), users/site (6.6e)	boxes (6.6a), color (6.6b), percentage (6.6c), time/-point (6.6d), users/site (6.6e)	boxes (6.6a), color (6.6b), percentage (6.6c), time/-point (6.6d)
Additional elements	Video tutorials, Tickets	Blog	Dropbox questions, Polls, Surveys	Choice activity, Workshop, Database activity, Glossary, Wiki, Blog, Surveys

Table 3.5: Unfulfilled feedback element requirements and additional available elements

The status of the submission in the open input fields is not explicitly pointed out (6.5b), it is recognized by the ability/disability to edit the field. Due date can be seen in the schedule, but is not explicitly mentioned next to each question (6.5e). No ranking of the answers through voting is possible (6.5i).

The labsystem has no graphical representation of the number of users or registrations per country/city/etc (6.6e).

Coursera's feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c). There is no option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a).

The platform does not have a Chat.

When it comes to the Quizzes, under the not included features is red/green coloring of wrong/right answers (6.4e). Status of the grading and time left are not shown (6.4g). The type of the right answer(s) after grading is not enhanced (6.4n). There is no option to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field (6.4p).

The open input fields do not allow saving progress before officially submitting it (6.5a). Corrected/uncorrected items are not colored (6.5c). Due date and remaining time are not shown (6.5e).

Coursera uses the gathered statistics for internal use. No graphical visualizations are placed at learners' disposal.

edX's feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c).

The platform does not have a Chat. A Forum is present. Posts, however, cannot be sorted by votes/date/etc.(6.3b)

Each question in the Multiple Choice Questionnaires has only one right answer (6.4o). Status of the grading (6.4g) and time left (6.4j) are not shown. The type of the right answer(s) after grading is not enhanced (6.4n). There is no option to flag a question (6.4l), to choose a certainty level (6.4m) and to choose an answer from a drop field (6.4p).

In open input fields corrected/uncorrected items are not colored (6.5c) and due date and remaining time (6.5e) are not shown.

edX uses gathered statistics for internal use. No graphical visualizations are placed at learners' disposal.

Moodle's feedback element Email does not allow linking an element to an email body in the system itself (6.1b) and also does not display a list of people who the email could be sent to (6.1c). There is no option available for learners to specify if they want to receive emails from organizations that represent the courses (6.1a).

When it comes to the Quizzes, time of submission (6.4c), number of used attempts (6.4i), status of correction/grading (6.4g) are not shown. The type of the right answer(s) after grading is not enhanced color (6.4n).

In open input fields there is no option to save progress before officially submitting it (6.5a). Corrected/uncorrected items are not colored (6.5c) and due date and remaining time (6.5e) are not shown. No ranking through voting (6.5i) is available.

Moodle does not have graphical representations of the answers with boxes, which are colored depending on the number of reached points (6.6a). Results are not shown in percentage (6.6c). There is no graph, which visualizes the time spent per gained point (6.6d).

3.5 New Artifacts - Review

In section 2.6 of the Analysis Chapter we discussed the following artifacts:

- (I) Graph depicting the whole lab process in time.
- (II) Visualization of the approximate time left until the end of the lab.
- (III) Visualization of worst answered MC and input questions.
- (IV) Visualization of additional multiple choice statistics - the absolute number of times each multiple choice answer has been chosen, as well as the distribution of 'clicks' for all answers in percentage.
- (V) Emotion/Like/Dislike feedback bellow each element.

Throughout the Related Work part of the thesis we reviewed the feedback elements in the Coursera, edX and Moodle platform and their features. We stated that the three platforms do not offer anything similar to those artifacts, except for the Time left feature in Moodle, which resembles (II). It, however, only shows a countdown until the end of a task and does not calculate time dynamically, according to a person's own pace. The three big platforms offer other elements, which are missing in the labsystem (e.g. chat, forum, blog, etc.). However, we do not consider any of them to be more advantageous than the above listed artifacts. We believe that they are more useful on a larger scale, when a larger number of participants takes part in the communication. Furthermore, they are not visualizing any statistics to learners. The only publicly available statistical feedback visualization is given by Moodle. However, it is also not suitable for our goals, as it works with a much larger number of participants and courses.

The ideas presented above are specific and do not just enable another communication mechanism, but also help to depict tendencies. They visualize statistics and give an overall course overview. They enable recognition of problems and support not only learners, but also instructors. The fact that they are missing in the other platforms, in our opinion, makes them even more interesting to develop and evaluate. For those reasons, we decided to implement three of them in the way presented above and in 2.6.

We do not implement the fifth artifact, as it requires more research into the area of what kinds of tasks do students "like". This artifact considers and indicates emotions

and preferences as cause for achievements. The first four artifacts consider foremost presence or lack of knowledge as cause for good/bad achievements. We leave this further research and the implementation of this artifact as a possibility for extension of this thesis.

We also decided to not implement the second artifact as it requires adaptation of the existing time tracking logic or a complete new implementation of it. We present details about the evaluation of the algorithm and this decision in Chapter 6.

3.6 Conclusion

In Chapter 3 we discussed the Coursera, edX and Moodle platform. We reviewed their feedback elements and created an overview-comparison of the missing features in all systems, including the labsystem. We saw that those three platforms are widely used all over the world and that because of that they also consider support, communication and statistics on a large scale. We saw that the labsystem does not lack any of basic feedback elements, except for chat and forum. When compared to the other platforms, it misses some features regarding the Multiple Choice questions and the Open input questions. However, it implements graphical visualizations and email features, which the others do not.

The just mentioned comparison with the three big eLearning platforms in the Related work was necessary in order to recognize whether there are any deficiencies in the labsystem, which should be addressed right away in order to reach this goal. My personal conclusion is that despite the fact that the labsystem misses some feedback elements, it fulfills the requirements for an eLearning environment, which creates a good learning process. It offers a simple and user-friendly interface. It provides help through video tutorials, as well as through different feedback elements. It endorses self-regulation through multiple choice questions and instructor-guidance with free input fields. It allows the creation of an isolated authentic learning environment, which can be combined with university study programs (as done with the ilabs at TUM). It, furthermore, implements graphical visualizations, which help learners to self-reflect and correct their performance.

Nevertheless, there is always place for improvement. Considering the reasons we discussed in 2.6 and 3.5, we decided to implement three further feedback elements, which aim to improve the learning process of the participants in the two ilabs. In the next Chapter (4) we present their concrete design and how their features contribute to fulfilling the purpose of the thesis. We also discuss possible design ideas for the two artifacts, which we decided not to implement, but which could be a continuation of our work.

Chapter 4

Design

In Chapter 3 we concluded that the labsystem has at its disposal all basic feedback elements, except for chat and forum. We also concluded that it fulfills the basic requirements for creating a good learning process. Nevertheless, we also stated that further improvements can be made. On base of the research that we did and the pedagogical best practices for a learning process and feedback that we pointed out in the Analysis, we grounded our decision to implement the following artifacts:

1. Graph depicting the whole lab process in time - (I).
2. Visualization of worst answered multiple choice and input questions - (III).
3. Visualization of additional multiple choice statistics - the absolute number of times each multiple choice answer has been chosen, as well as the distribution of 'clicks' for all answers in percentage - (IV).

What we discussed in previous chapters, served as theoretical reasoning and background for our choice of artifacts. In this chapter we discuss and justify our concrete design decisions for each one of them. Hereby, we divide them into two categories - time analysis and worst answered questions.

Note: Subsection 2.2.2 of Chapter 2 introduced the core elements of the labsystem - **page, multiple choice, input, collection, lab** and **schedule**. Understanding the concept of the elements is important for understanding the design and the implementation logic behind all artifacts.

Note: This chapter discusses how could the previously presented (II) Time left and (V) Emotion feedback artifacts be designed. We decided to not implement them as a part of this thesis. However, we leave possible design ideas for how our work can be continued.

4.1 Time Analysis

In this section we talk about artifacts (I) and (II). They both belong to the same category - time analysis, since they both belong to the same working flow. The concept and stages of this flow are presented here. The concrete design of each stage (artifact) is discussed in detail in the following subsections.

The **first stage** of the time analysis process is the development of the logic behind the whole lab process artifact (I). It identifies time needed for:

1. Question elements (m, i).
2. (Optional) Collection elements (c, C).
3. States (Prelab, Lab, Correction).
4. Topic (overall time for all states).

For the first point (1) we use and extend the algorithm (2.2.3) used to create graph 2.6, which was discussed in Chapter 2. It identifies time spent for m and i elements. This allows to (optionally) calculate the time for each collection - time spent per page with elements. Most importantly, it helps to calculate the time spent for the three different states of a topic - prelab, lab and correction.

The **second stage** of the time analysis would then be the implementation of an extrapolation feature - time left artifact (II). Such feature can be based on:

1. Credits or
2. Other teams' results.

By the second option (2) there are three main implementation possibilities - with data from teams from the current term/ from the previous term/ from all terms.

The **third stage** of the time analysis is the creation of the actual visualizations. It can be seen as a sub-stage by the above-mentioned stages. For each artifact there are different visualization possibilities. Our visualization choices and the reasoning behind them are presented in the following subsections.

4.1.1 Time analysis of the whole lab process (I)

This subsection is about the first artifact - the time spent for each ilab topic and all parts of it - namely prelab, lab and correction. It starts with a mock-up of its visualization, so that it is easier for the reader to imagine the end goal of the methodology presented later.

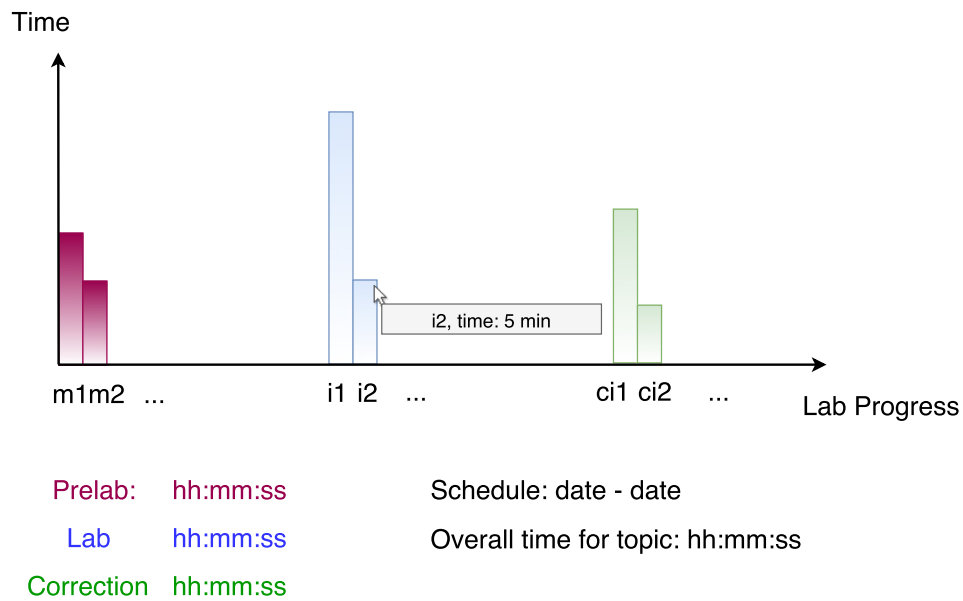


Figure 4.1: Time evaluation of the whole lab process

The **visualization** of the time evaluation consists of two parts. The first part consists of three bar charts. Each chart depicts the average time spent for each question element during each part of a topic - prelab, lab and correction. This gives an insight into time problems by particular elements. Our first idea was to implement only one chart. However, the big number of questions in each topic makes such visualization hardly readable. This is why we decided to implement a separate chart for each state.

The second part shows summary statistics in plain text. Those statistics include the average overall time spent for one whole topic, as well as the time distribution of the three parts separately. On one side, this aims to give a compact overview of the overall course workload. It can be used for quick comparison between measurements from different semesters. On the other side, such statistics can help for the recognition of problems occurring in a particular part. For example, if extensions are constantly requested each semester for finishing a certain lab, or the opposite - if students finish the lab exercises much earlier each semester. This information can be used to adapt the contents of the lab (e.g. to reduce or increase number of exercises). The artifact can also be used to recognize when the correction of a certain lab takes more time than expected, so that the working hours of the correctors can be adapted accordingly or so that the need of more correctors is recognized.

The **audience** of this artifact are the instructors (tutors and advisers). Its **purposes** can be summed up to five main points. First - help instructors to recognize time related issues. Second - help instructors to get an overview of the course workload. Third - help instructors to make a comparison between duration of different parts of the labs from different semesters. Fifth - make the learning process more transparent

and adaptive.

The **implementation** of the artifact requires the following.

- Input:
 - All events in the database log for each prelab and each lab. This means for each event:
 - * idx - its index;
 - * resource ID - the element by which it occurred (e.g. i5);
 - * referrerID - the element which referred to the element by which it occurred (e.g. c24.i5);
 - * timestamp - the time when it occurred;
 - * action - its type (e.g. 15 - lCorrectorSave);
 - * teamNr, userID - identification of the person by whom it occurred.
 - The existing time analysis algorithm (2.2.3).
- Processing algorithm:
 - Identify time for each prelab by:
 - * Identifying times for all m elements in the prelab with the existing time analysis algorithm.
 - * Summing up those times.
 - Identify time for each lab by:
 - * Identifying times for all i elements in the lab - analog to the m elements in the prelab.
 - * Summing up those times.
 - Identify time for each correction by:
 - * Identifying times for all i elements spent by a corrector using a slight modification of the existing time analysis algorithm.
 - * Summing those times up.
 - Identify time spent for each topic by:
 - * Summing up the time intervals for prelab, lab and correction.
 - Visualize the data in pie charts and text.

4.1.2 Time left (II)

For the Time Left artifact we have the following two **visualization** ideas.

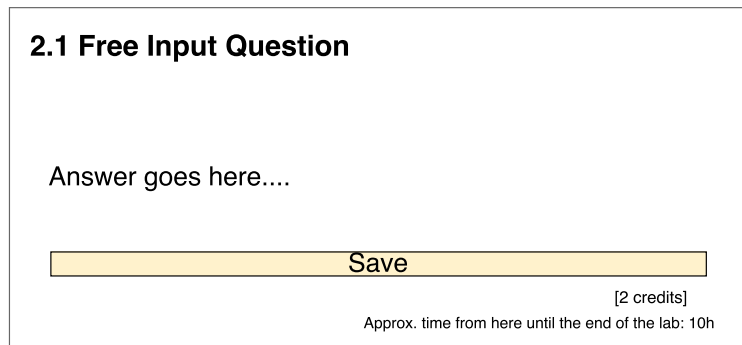


Figure 4.2: Time left. Idea 1: display time left on the bottom of each i element.

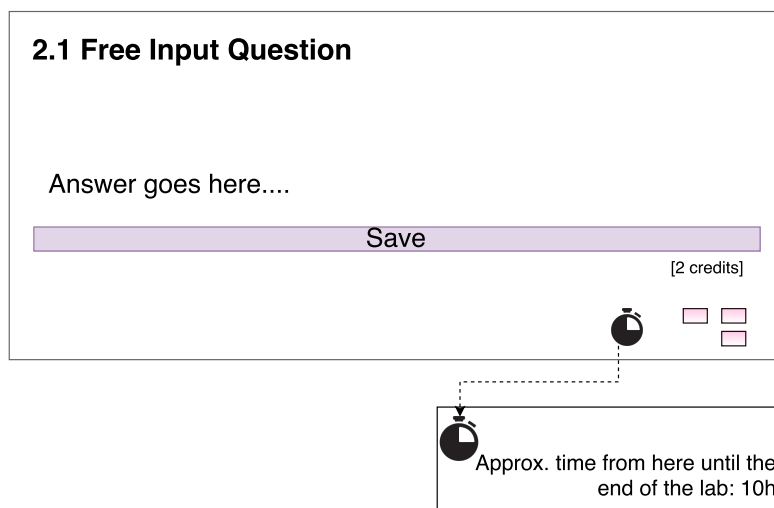


Figure 4.3: Time left. Idea 2: implement a button which displays the time left.

We consider the second idea (Figure 4.3) more advantageous. We believe that displaying unwanted information constantly (Figure 4.2) decreases the readability of the element and could increase learners' frustration. This is why the user should be given the possibility to display this information only when they needed it. For the goal an additional button could be implemented at the right bottom side of the element. It can display the approximate time left in hours and minutes in a separate field. As this is additional optional information, it should be easy to find, but not focused on.

The **audience** of this artifact would be the learners. Its **purpose** is to increase their self-reflection. It shall give them the opportunity to better assess their pace, which is usually an indication of the level of knowledge they have reached through self-

preparation. They would be able to assess their performance according to the average performance of their peers' results and the time left according to their own pace. This can help them to recognize that e.g. a higher level of self-preparation is needed or that they should strive to keep their current performance level.

The visualization can also be helpful in the way that during the exercises learners can recognize if they spent too much time on a task and optimize the organization of the remaining time.

At the beginning of this section we mentioned that the time left is the second stage of the time analysis process. We also mentioned two possibilities for what the processing algorithm of the artifact can be based on. The first one are the credits for each question in each lab. The second one - the results of other teams.

The **implementation** of the first possibility would require the following.

• **Input:**

- Time stamps of all input elements;
- $I = (i_1, \dots, i_n)$, where i - input element, n - max number of i elements in a particular lab;
- $T = (t_1, \dots, t_n)$, where t - potential time of an input element in a particular lab;
- $C = (c_1, \dots, c_n)$, where c - credits for an input element in a particular lab.

• **Processing algorithm:**

- Get the credits for each input element: $i_1 \rightarrow c_1, \dots, i_n \rightarrow c_n$
- Calculate time for each input element: $i_1 \rightarrow t_1, \dots, i_n \rightarrow t_n$, where each t_k is the sum of all time intervals for edits of input element k
- For each input question k after the first edited one:
Calculate probable time, on base of time spent on previous questions:

$$c_k / (c_1 + \dots + c_{k-1}) = t_k / (t_1 + \dots + t_{k-1})$$

$$\Rightarrow t_k = (c_k * (t_1 + \dots + t_{k-1})) / (c_1 + \dots + c_{k-1})$$

Coming to the second possibility, what needs to be discussed is who are "the other teams". At the beginning of the section three main possibilities were mentioned - teams from the current term, teams from the previous term, teams from all terms. We believe the results of the teams from the current term, as well as those from the previous term to be most relevant.

Considering that each team does the lab exercises on a different day, displaying only average time needed by the teams of the current semester is not sufficient. The reason is that the first team, which starts working, does not have any other teams' results for comparison. The biggest advantage has the team starting with the lab last, as it has the average results of all other teams.

However, as every semester the lab contents are improved and changed accordingly, the most accurate comparison should be the one with results achieved with the current lab contents. This is why we suggest implementing both methodologies.

Considering results of the teams from the previous term allows the first team to have a comparison base as well. Assuming that there are no major changes made for the current term, this base is expected to be accurate. Considering results of the teams from all terms is not expected to give more accurate results because of the changes made every semester.

The **implementation** of this artifact would require the following.

- Input:
 - Average data of the other teams;
 - A methodology for time evaluation of the whole lab process. For example, the one that we develop in this thesis 4.1.1.
- Processing algorithm:
 - After closing each m/i element the algorithm shall simply calculate overall time for the lab minus time for the remaining elements. Time for each element would be calculated with the time evaluation methodology.

4.2 Worst answered questions

In this section we talk about artifacts (III) and (IV). We first go into detail about the logic behind (III) - the worst answered multiple choice and input questions. After that we continue with (IV), as it is a continuation of the logic behind the worst answered multiple choice questions.

4.2.1 Worst answered MC and input questions (III)

We considered the following **visualization** ideas for the artifact.

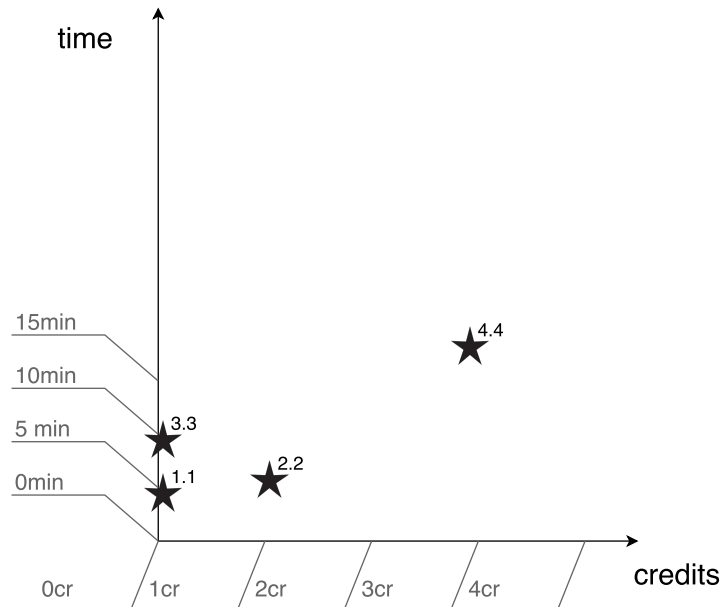


Figure 4.4: Worst answered questions for 4 credits. Idea 1: questions divided into categories according to maximum credits possible.

MC Question idx	Absolute number of attempts	Average number of attempts
1.1	38	2.5
3.3	37	2.3
2.2	32	2
4.4	26	1.6
:	:	:

Figure 4.5: Worst answered MC questions. Idea 2: questions ordered in a table according to the average number of attempts for each question / their order in the prelab.

iQuestion	Possible credits	Average given credits	Difference
1.1	4	0	4
3.3	3	0	3
2.2	4	2	2
4.4	2	0.5	1.5
:	:	:	:

Figure 4.6: Worst answered input questions. Idea 2: questions ordered in a table according to the difference between possible and given credits / their order in the lab.

We first considered dividing the questions into categories according to the maximum number of credits that can be reached. Our first idea (Figure 4.4) was to implement a graph, which depicts the distribution of questions from one lab from one category according to credits (x-axis) and time (y-axis). Such visualization gives a compact overview of all questions. It could, however, get very unclear when many questions are answered for the same time and when the same number of credits is gained.

In comparison to it, our second visualization idea (Figure 4.6 and Figure 4.5), which we decided to implement, gives more structure and clarity. It presents one category of questions (multiple choice questions/input questions) in a table.

The table from Figure 4.6 visualizes the possible number of credits and the average number of actually given credits for each input question. We considered sorting the tables according to the average difference (for the input questions) and according to the average number of attempts needed for each question (for the multiple choice questions (Figure 4.5)). However, we decided against that. Instead the tables are to be sorted according to the order in which the questions occur in the prelab/lab.

The **audience** of this artifact are the instructors (tutors and advisers). The **purpose** of those visualizations is to help for the recognition of problematic contents and to eventually provoke adaptation of those contents. The artifact can also be used to make an emphasis on the misunderstood contents during the lecture. This aims to increase the understanding of the material and the engagement of the learners in the courses.

The **implementation** of the artifact requires the following.

- **Input:**
 - All student answers per multiple choice question in a prelab;
 - All student answers per input question in a lab.
- **Processing algorithm:**
 - Multiple choice questions: worst (biggest) number of attempts.
 - * For each MC question:
 - Count the absolute overall number of attempts to answer a multiple choice question (*numberAttempts*).
 - Count the number of given user-answer-instances (*numberMCInstances*).
 - Calculate the average number of attempts *avgNumberAttempts* by dividing *numberAttempts* by *numberInstances*.
 - * For all MC questions:
 - Get the relevant values for all questions and feed them into an HTML table.

- Input questions: worst (lowest) number of credits.
 - * For each input question:
 - Calculate the number of given credits from all instances:
givenNumberOfCredits
 - Calculate the number of user-answer-instances:
numberInputInstances.
 - Calculate the average number of given credits:
avgGivenNumberOfCredits.
 - Calculate the *differences* between the *possibleNumberOfCredits* and the *avgGivenNumberOfCredits*.
 - * For all input questions:
 - Get the relevant values for all questions and feed them into an HTML table.

4.2.2 Additional statistics for multiple choice questions (IV)

The **visualization** idea we considered for the (IV) artifact is the following.

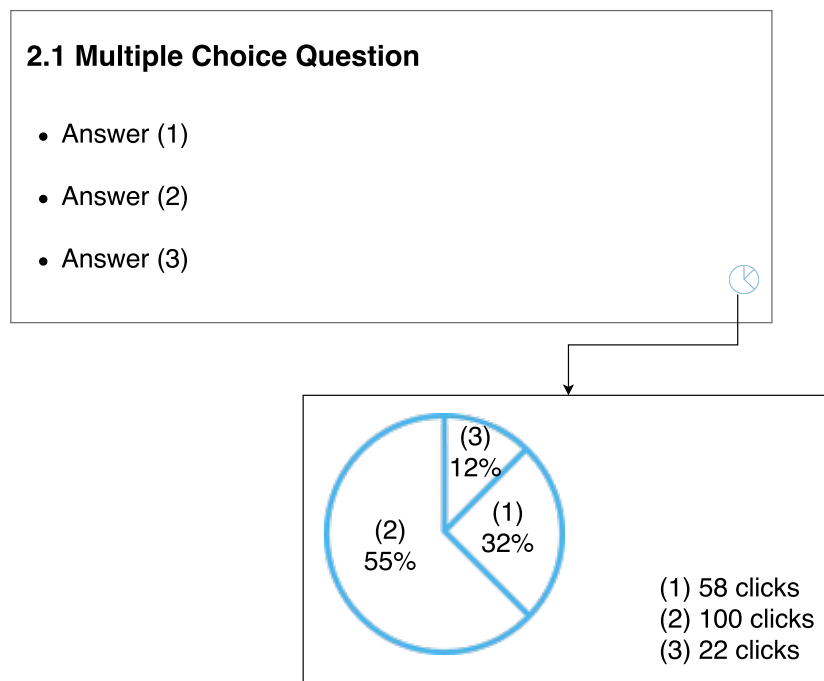


Figure 4.7: Additional multiple choice statistics

For the visualization of the Multiple Choice statistics we considered to implement a button at the right bottom side of the element. We had this idea, as at first we considered visualizing those statistics to students. Accordingly, as for the Time left artifact, we do not consider constantly displaying such information appropriate.

However, we then decided that the **audience** of the artifact shall be the instructors (tutors and advisers). This led us to believe that generating a separate page with all statistics displayed directly is the best choice.

The generated page displays information about the number of clicks per answer above each question in plain text. This aims for simplicity. A pie chart above each question depicts how many of the participants have chosen each answer (in percentage). We chose this type of chart as it is most suitable when presenting categorical data. In our case each answer is a category. A "requirement" by pie charts for better visibility is that there should not be more than six categories in one chart [30]. The design of the Multiple choice questions in the two ilabs fulfills this requirement.

The **purpose** of those multiple choice statistics is similar to the one of the visualization of worst answered multiple choice questions (4.2). Those statistics also aim to point out problematic questions. The difference is, that they give more detailed information about where exactly did the problem occur. They point out problematic answers. More clicks indicate misunderstanding of a concept. These statistics make it possible for instructors to emphasize on specific details. This aims to cover possible knowledge deficits. It shall lead to better results in the graded exercises as well and ultimately - to a higher level of motivation of the learners.

The **implementation** of the artifact requires the following.

- **Input required:**

- Clicks per answer for all answers, for all MC questions.

- **Processing algorithm:**

- For each MC question: For each given instance of the question:
 - * Calculate the absolute number of clicks for each given answer *numbeClicksAns*.
 - * Calculate the overall clicks for all answers *overallNumbeClicksAllAns*.
 - * Calculate the ratio in percentage:


$$rato = (numbeClicksAns/overallNumbeClicksAllAns)*100.$$
- For all questions:
 - * Get the relevant values and feed them into pie charts.

4.3 Emotion feedback (V)


2.1 Free Input Question

Answer goes here....

[2 credits]



Like



Dislike

Figure 4.8: Like, dislike feedback

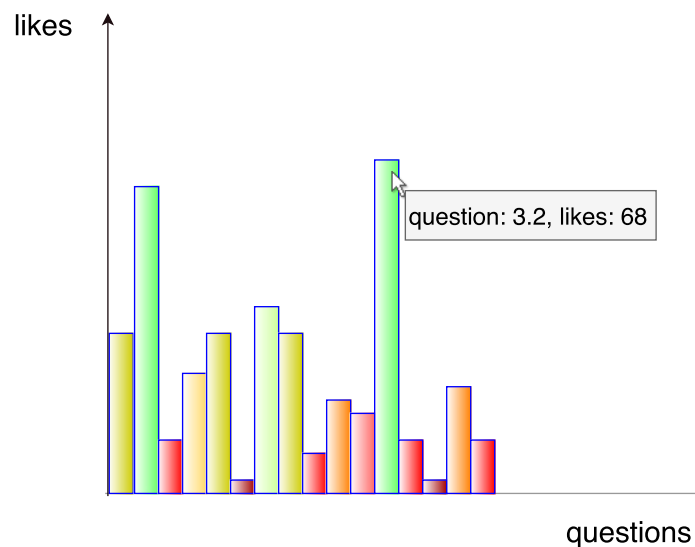


Figure 4.9: Emotional feedback - statistics

A possible **visualization** idea for emotional feedback would be to implement two more buttons on the right bottom side of each free input element. Our belief is that learners are more keen to giving simple like/dislike feedback, rather than explaining what exactly they find good/bad in the different questions.

The data gathered with those elements could be structured in a bar chart. The element should indicate tendencies. Most interesting to see are the big amplitudes - by which questions do highest and lowest values occur.

The **audience** of the element would be both learners and instructors. The **pur-**

pose of the element would be to gather a lot of emotion-related feedback, which will indicate which types of questions are preferred or disliked by students. Based on the results, the contents could be changed in a way, which includes more of the types of exercises which are considered better/more useful by the learners. This would increase the authenticity of the platform, as well as the interest of the students in the learning process.

The **implementation** of the artifact would require the following.

- **Input:**
 - Number of likes/dislikes for each question.
- **Processing algorithm:**
 - Count, compare and order questions according to the number of likes.

Chapter 5

Implementation

In this Chapter is discussed the implementation of three of the artifacts whose design was discussed in Chapter 4. The chapter discusses the input used from the databases and explains the logic of our code.

In order to start with the details, the structure of the lab system's backend needs to be briefly described. It consists of three databases. The first one (*data database*) holds persistent data, such as the texts from theory parts. The second one (*working database*) holds short-life data, e.g. users' answers and the third one (*user database*) - user data. Each element in this database is uniquely identified by its index *idx*. [12]

5.1 Time Analysis of the whole lab process (I)

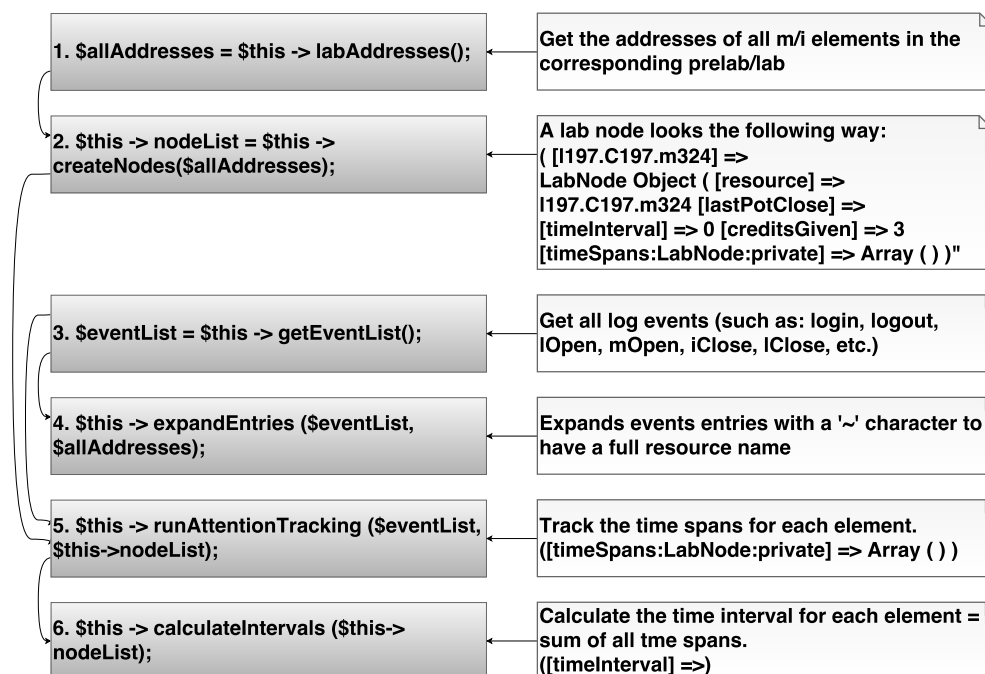
The time analysis identifies time spent by *students* for all *m* elements in a prelab, as well as for all *i* elements in a lab. It also identifies time spent by *tutors* for the correction of all *i* elements in a lab. Furthermore, average and absolute time spent for each state - prelab, lab and correction, as well as absolute time spent for a topic (all states together) are calculated. The main steps, through which the implementation of the time tracking on an element goes, can be observed in Figure 5.1.

Firstly, the addresses of all *m* and *i* elements are retrieved from each relevant lab topic and a list of lab nodes is created from those addresses. A lab node has the following example structure right after its initialization: *LabNode Object* (*[resource]* => *16.C46* [*lastPotClose*] => [*timeInterval*] => *0* [*creditsGiven*] => *0* [*timeSpans*] => *Array* ()). It is a structure holding information about the element. It contains the name of the element, the given credits for it and the closing event, which caused the time tracking for the element to stop. It, furthermore, helps to store and give easy access to the times tracked on the element.

The second step is making three queries to the database - one for each state (prelab, lab, correction), to get all relevant event actions from the *event_log* table. This

is done by taking under consideration the start and end of the schedule of each lab. The reason is that only the time spent on the elements during the specified semester is relevant for the time tracking. Otherwise, time spent during previous/following semesters will be added to it.

Each prelab needs to be completed in order for a lab to be accessible for a student. This is why the schedule for a lab is also time limitation for the prelab of the same topic. However, the correction, although possible before end of the schedule, usually starts after it. This is why for its query only the start date of the schedule is specified. After the event list for each state is retrieved, each entry in each list is expanded to have a full resource name (e.g. C24.c15.c13.m8). This allows to see in which collections the element belongs and to link the address of the element to the element itself. Otherwise the name would have the form e.g. m8.



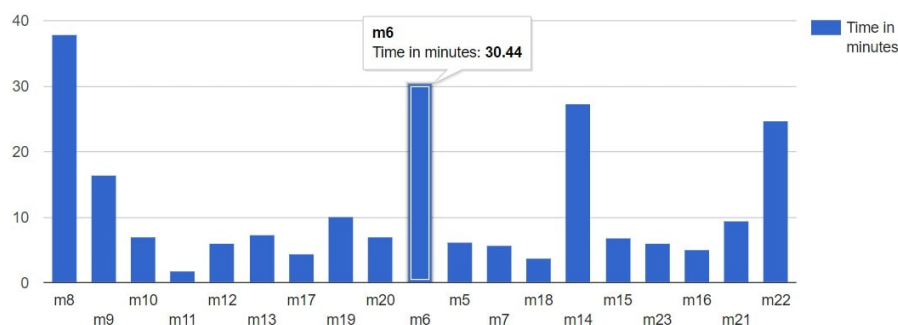
interval is the sum of all tracked time spans.

The time for the prelab is considered to be the sum of the time intervals of all m elements, which are a part of the prelab. Accordingly for the lab - the sum of the time intervals of all i elements, which were a part of the lab.

In order to calculate the time spent for the correction in a topic, we created an adaptation of the logic behind the attention tracking (step 5 in Figure 5.1), the time spans adding and the intervals calculating (step 6 in Figure 5.1) functions. The function `addTimespan($start, $end, $role)` is called by `runAttentionTracking($eventList, $nodeList)` (step 6, Figure 5.1). It adds the tracked times for each element to the array `timeSpans` in the lab node structure of the element.

With the newly created `runCorrectionTracking($eventList, $nodeList)`, `addTimespanCorrection($start, $end, $role)` and `calculateCorrectionIntervals($nodelist)` we track actions and calculate intervals for actions recorded in a *corrector's* (instead of a *student's*) role. Having done this, we then use the same logic to calculate times for the correction of all i elements.

The correction time interval is considered to be the sum of the time intervals of all i elements, spent in a corrector's role. The overall time interval for a topic is then the sum of the time intervals of all above-mentioned states.



Overall average time for this prelab: 3:43:24

Overall absolute time for this prelab: 55:51:03

Figure 5.2: Time Analysis of the prelab. Actual visualization - bar chart.

For visualizing the statistics in bar charts, we use the open source library *gChart-ToolPHP*, which is published under the GNU General Public License [31]. *gChartToolPHP* is a PHP wrapper for the Google Chart API [32], which is actually based on JavaScript.

A specificity of this wrapper is that it cannot embed multiple graphs containing different data on a single page. This is not a limitation of the Google Charts API, but of the wrapper. When calling the corresponding functions to create a chart, *gChart-*

ToolPHP creates all necessary JavaScript functions and variables and embeds them in HTML tags. This generic creation of the code asks for identifiers when a user wants to show several charts on a single page. This creates a problem, because all graphs are called with the same identifier (the id of the last graph on the page). To deal with the problem, three steps had to be done when the wrapper was called. We also had to change the code of the library itself. Details follow in the next paragraphs.

In order to explain the details around the steps, we use Figure 5.2 and Listing 5.1. Listing 5.1 shows the code for creating the time analysis bar chart of the prelab of each topic in minutes. Figure 5.2 shows the actual visualization.

Listing 5.1: Code used to create the time analysis bar chart of the prelab.

```
// create bar chart for the prelab in minutes
$dataMmin = array ();
$colsMmin = array ();
for ($k = 0; $k < count( $mElementIndexes ); $k++){
    array_push($dataMmin ,
        [$mElementIndexes [$k] , $mAvgElTimesMin [$k] ] );
}
$colsMmin = [ [ ' type ' => ' string ' , ' label ' => ' Index ' ] ,
    [ ' type ' => ' number ' , ' label ' => ' Time in minutes ' ] ];

$mMin = new gChartTool\gChartTool ();
$mMin->setChartDivId (" mMin ");
$mMin->setIdentifier (" mcMin ");
$mMin->setVisualization ( ' column ' );
$mMin->SetAllTableColumns ( $colsMmin );
$mMin->setAllTableRows ( $dataMmin );

$pge->put ($mMin->getGoogleJsapi ()
    . $mMin->loadGoogleChart ()
    . ' < div id = " mMin "
    style = " width : 1000 px ; height : 400 px ; " >
    < / div > ' );

$pge->put ( ' < div style = " border : 2px groove #66b9d8 ; " >
    < p > < b > Overall average time for this prelab < / b > : '
    . timeLength ( $avgOverAllTimePrelab ) . ' < / p >
    < p > < b > Overall absolute time for this prelab < / b > : '
    . timeLength ( $overallTimeForPreLab )
    . ' < / p > < / div > ' );
```

The wrapper takes two arrays as input. The first one - *\$colsMmin*, contains the types and the names of the columns (in our case *Index* and *Time in minutes*). The second one - *&dataMmin*, contains the actual data that is to be presented by the bars (the indexes of the *m* elements and time intervals for each element in minutes).

When creating a chart, the first of the needed steps is to set the identifier of the chart to a unique value (unique in comparison to the ids of the other charts on the same page). This is done by using the function *setIdentifier(\$identifier)*, provided by *gChartToolPHP*. Another step is to set the identifier of the *div-html* element, which is responsible for showing the created chart on our page. In addition to that for every *div-element* the *style-attribute* gets values for *with* and *height*, to represent the charts in the desired format. The third step is that the chart needs to be created by the following two functions: *getGoogleJsapi()* and *loadGoogleChart()*. The first one produces the JavaScript code needed to include the Google JSAPI library and the second one - the JavaScript code needed to construct and display the chart [31]. The function, which is usually used to create the chart, is *drawPage()*. It produces a complete HTML page and "cannot be used in embedding" [31].

When it comes to the changes in the library code, we adapted the following functions. The above-mentioned *loadGoogleChart()* is now set to use the unique identifier of each graph when creating it. The function *loadGoogleToolBar()*, which produces the JavaScript code needed to construct and display the Google toolbar [31] is now set to accept each unique identifier. The *preLoadDataSource()* and *instantiateDataSource()* functions, which load and instantiate the Google visualization data sources, are now also set to use the unique identifiers, instead of the same variable for every chart.

5.2 Worst answered questions (III)

5.2.1 Worst answered multiple choice questions

Each multiple choice (MC) question can have a different number of given (and correct) answers. For an answer to be answered correctly, all of the correct answers have to be checked (chosen, "clicked"). When not all of the correct answers have been checked or/and a wrong answer has been checked, the attempt to answer the question is considered failed by the system. A student has three attempts and after that the correct answers are automatically displayed. Accordingly, the worst answered MC questions are those, by which learners need most attempts to answer correctly, or with other words - those with most scored failed attempts.

The visualization of this feedback element is a table with three columns: first - index of the question, second - absolute number of attempts, third - average number of attempts. Figure 5.3 shows the actual implementation of the table.

For the implementation of this table we need information from all three databases.

Figure 5.4 helps to explain the implementation flow. From the *working database* we make use of the table *multiple_choice_answers*. In this table is contained information about the questions indexes, about the user answers (which are saved as bit masks) and the user IDs for the corresponding answers. All user IDs are to find in the *user database*, together with further information about the users. From the *data database* we use information contained in the tables *collections* and *multiple_choices*. The first table contains the collections with multiple choice elements, which are part of the prelabs. The second one contains the correct (solution) bit masks for the multiple choice questions.

When it comes to the learning elements of the system, at first we thought about implementing the new functionality as an addition to the **I(ab)** element. However, this would have had the disadvantage that user data would not be accessible before the prelab is finished. This is why we decided to do it the following way. We get the prelab status and the user data with the existing functionality of the **I** and **m** element. Then we use the information to implement the new feedback element as functionality of the **c** element.

We iterate through all MC elements in the collections and for each element we get all user-answer-instances. Using this data, we calculate the absolute, as well as the average number of attempts per question. At the end we structure the information in an HTML table and display it in a page, generated by the **l** element.

IPv6 part 1

2012-2016: Lukas Schwaighofer, 2011: Philip Daubmeier, Philip Lorenz, Ferdinand Mayet, Marc-Oliver Pahl

MC idx	Absolute number of attempts	Average number of attempts
I5.C20.m8	39	2.2
I5.C20.m9	37	2.3
I5.C20.m10	17	1.1
I5.C20.m11	18	1.1
I5.C20.m12	17	1.1
I5.C20.m13	32	2
I5.C20.m17	27	1.7
I5.C20.m19	23	1.4
I5.C20.m20	29	1.8
I5.C20.m6	37	2.3
I5.C20.m5	25	1.6
I5.C20.m7	26	1.6
I5.C20.m18	28	1.8
I5.C20.m14	25	1.6
I5.C20.m15	37	2.3
I5.C20.m23	33	2.1
I5.C20.m16	28	1.8
I5.C20.m21	27	1.7
I5.C20.m22	31	1.9

m8 (1) Which of the following IPv6 addresses are syntactically correct (Note: The address list introduced above is not exhaustive. Check the RFC if you are not sure whether an address is valid.)? Visible in "c" only. 🗑️ 🔄 📄

::127.0.0.1

1:192.168::1

Figure 5.3: Worst answered multiple choice questions. Actual visualization - table snippet.

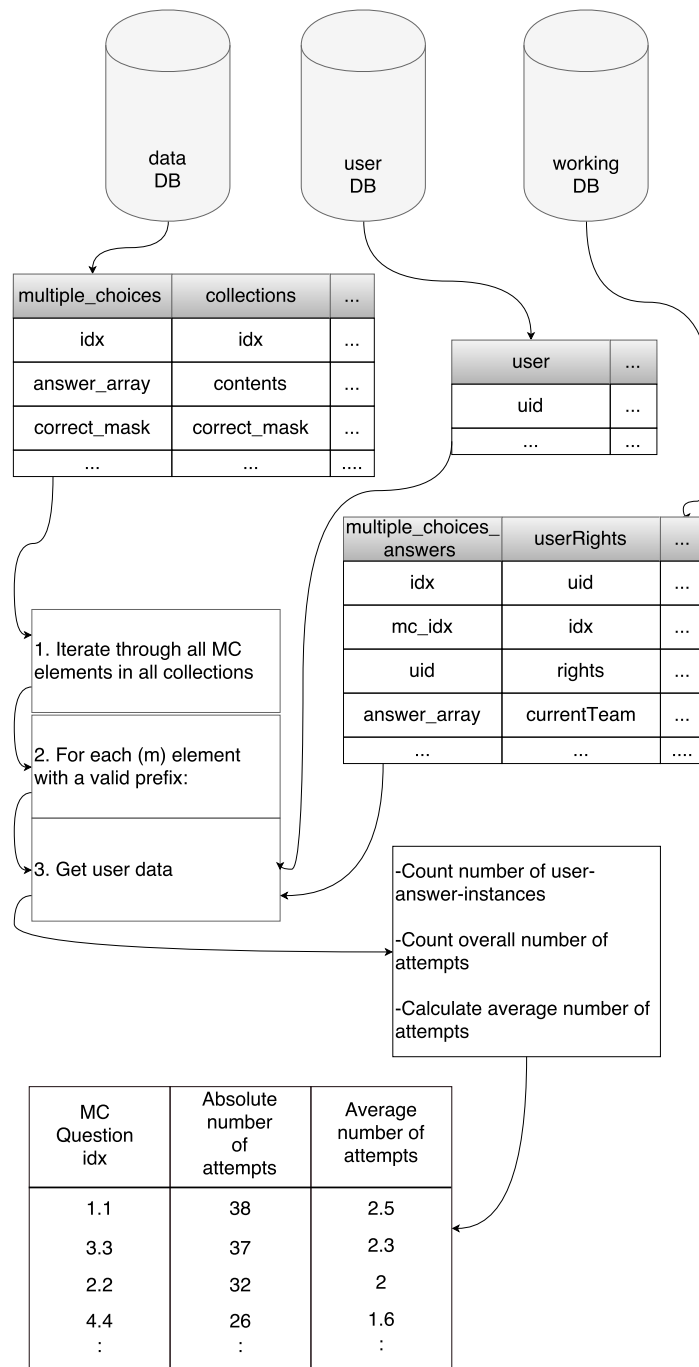


Figure 5.4: Worst Answered Multiple choice questions, Logic

5.2.2 Worst answered free input questions

As comparison base for the worst answered input questions we take credits. For each question the possible maximum of credits varies. This is why we cannot simply state

that the worst answered input questions are those with least given credits. We need to calculate the difference between the average possible and the average given credits for each question. The worst answered questions would then be those with the biggest difference.

We implement a table with four columns: first - number of the question, second - average possible credits, third - average given credits, fourth - average difference for the question.

A scheme of the logic behind the implementation of this artifact, you can see in Figure 5.5. Relevant from the database are the tables *inputs (data DB)* and *input_answers (working DB)*. From the first one we get the number of possible credits for each input question. From the second one the question index, as well as the given credits for each team, together with the corresponding team number.

We solve the task the following way. For each input question we get all user-answer-instances. We calculate the number of given credits for all answers and the average number of given credits for each question. Then we calculate the difference between the average possible given credits and average given credits for each question. At the end we structure the information for all questions of the lab in an HTML table and visualize it on a page generated by the `l` element.

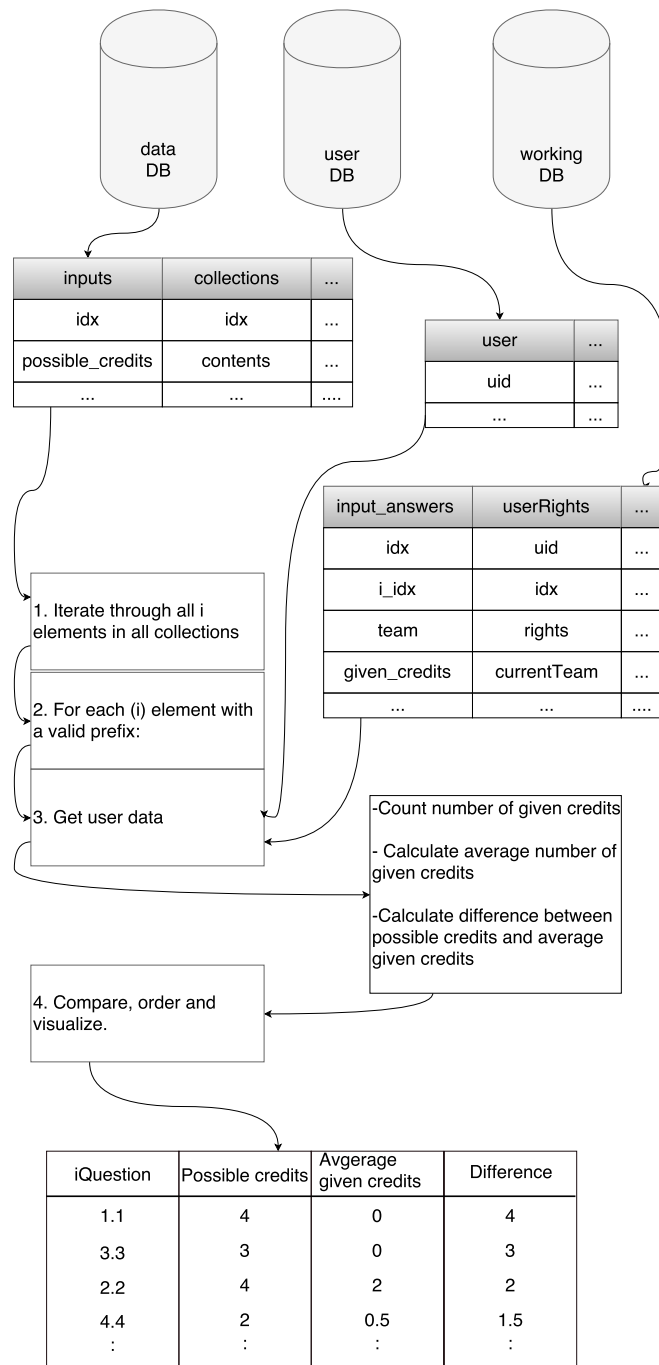


Figure 5.5: Worst Answered Input Questions, Logic

5.3 Additional statistics for multiple choice questions (IV)

For the multiple choice statistics the same tables from the database are used as by the Worst Answered Multiple Choice Questions.

Here, however, we use the information to calculate and visualize for each question the absolute number of times each answer has been checked, as well as the ratio between the checks for one answer to the checks for all answers of each question in percentage.

We look at each question, at each given user-answer-instance and implement a counter for each answer. We iterate through all attempts of each user and increment the counter of each answer when it has been checked. At the end we visualize the statistics for each question in absolute numbers and in percentage (in a pie chart).

For the visualization of the pie chart we use an external library, called gChartPHP [33]. Its function is the same as the function of the wrapper gChartToolPHP, which we used for the creation of the time analysis charts. It differs in that that it uses an older Google Chart API, which does not offer interactive graphs.

The reason why we use this tool is that our fix for embedding charts on the same page with the gChartToolPHP wrapper does not solve the problem when embedding the charts recursively. And the functions, which create the charts by this artifact, need to be called recursively for each question.

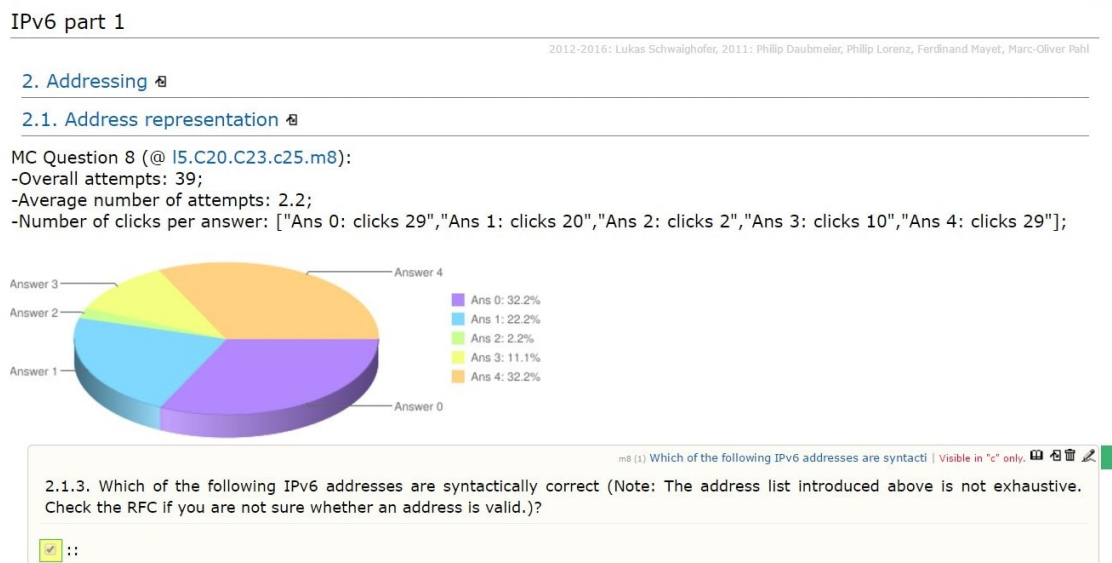


Figure 5.6: Additional multiple choice statistics, Actual visualization

Chapter 6

Evaluation

The goal of this thesis is to improve the learning process of all participants in the two ilab practical courses, conducted at TUM. We achieve this goal by implementing three feedback elements. Each one of which contributes to the fulfillment of a different requirement, specified in 2.3.1.

Table 6.1 shows the elements and the requirements to which they contribute.

	Simplicity (1.1)	Interactivity (1.2)	Diversity (1.3)
1. Time evaluation of the whole lab process in time, consisting of a bar chart and statistics in plain text.	✓	✓	✓
2. Identification of worst answered MC and input questions, presented in separate table visualizations.	✓		✓
3. Presentation of additional multiple choice statistics in pie charts and plain text.	✓		✓

Table 6.1: The newly implemented artifacts and which requirements for a good learning process do they contribute to.

The above-mentioned visualizations are not included to the already existing lab page views. Instead, each one is shown on a separate web page. This contributes to clarity and better readability, as no additional information is displayed when not needed. This improves the Simplicity requirement (1.1) for a good learning platform, specified in Chapter 2.

The first artifact gives a simple overview of the results of each lab topic, as well as a detailed "report" about each element in it. This contributes to the Diversity requirement 1.3. The external library we use helps for the creation of an interactive visualization (5.2), which presents the relevant data in a clear straightforward way. (Interactivity 1.2) This visualization can help instructors to quickly recognize different time related issues.

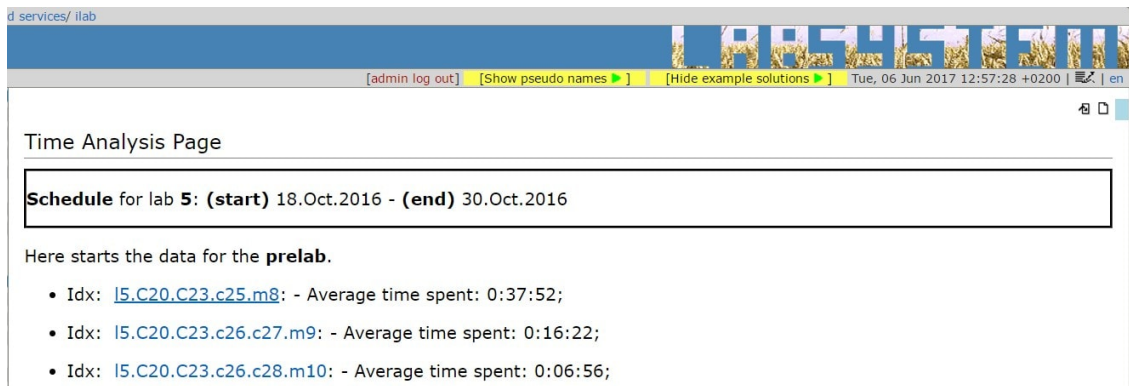


Figure 6.1: Time Analysis of the prelab. Actual visualization - text snippet.

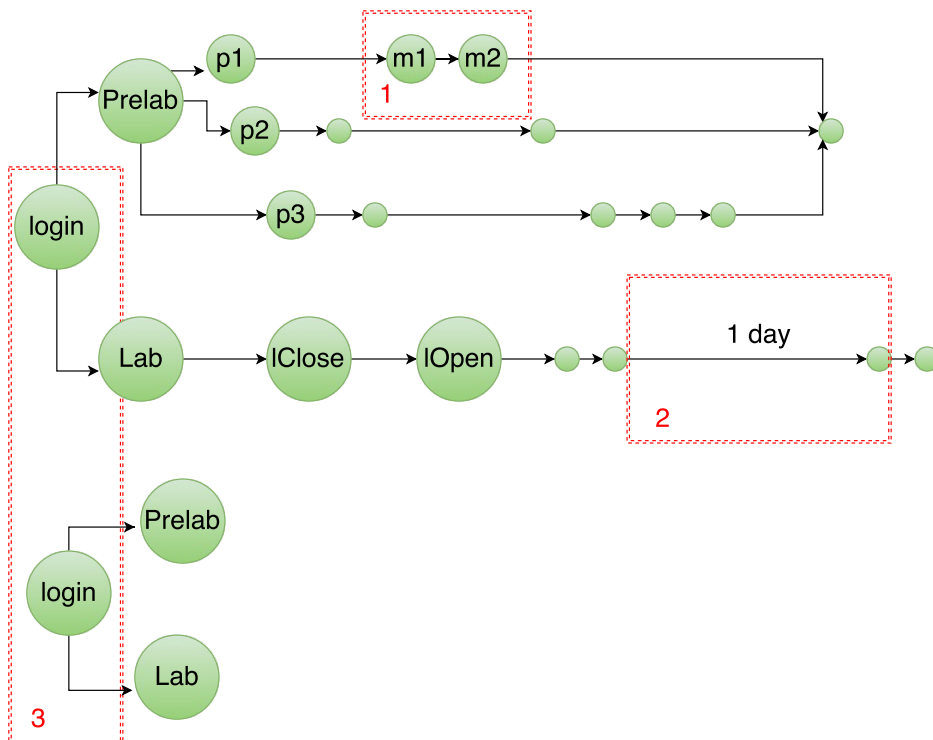


Figure 6.2: An example flow of events in a topic. Help-mock-up for the qualitative assessment of the time analysis artifact.

Furthermore, we made the decision to display the exact time for each element separately in an hours:minutes:seconds format above each graph. We also link each index to the element itself. This enables instructors to directly go to the content of the desired question without having to search for it.

The implementation of the artifact is based on the labsystem's already existing time tracking algorithm (2.2.3). This algorithm helps to calculate the time spans for each m and i element in a lab instance. It, however, has its downsides. They can lead to a certain level of inaccuracy.

With the help of Figure (6.2) we explain three points, which provoke such inaccuracy.

The algorithm assumes that the time spent on all non-question elements (e.g. p) before answering a question element (e.g. m) is preparation time for this question element. Accordingly, the time is added to the time interval of the question element. However, this assumption seems to be incorrect, when a participant answers two question elements consecutively (1 in 6.2). There is a high possibility that the preparation time for answering the second question was spent before answering the first one and assumed as time for the first one. The existing algorithm does not have a solution for this problem.

Second problem (2 in 6.2) occurs when there is no closing/logout event happening. For example, when the team makes a pause for a few hours or leaves the exercises open for the night. For this case the algorithm has a timeout of 60 minutes implemented. The question is how accurate is this assumed timeout and can a better assumption be made.

The third problematic concept (3 in 6.2) is that there are always two people working in a team. Time should not be taken under consideration twice. However, as the two people do not necessarily have the exact same elements open all the time, the solution cannot simply take the time spent by one participant. Furthermore, this concept makes it difficult to track how much preparation time exactly is spent for each element. Quickly going back to 1 in the graph: it could be the case that team member 2 is reading about the question m_2 , then the team member 1 is actually answering it and team member 1 is answering question e.g. m_3 . Then the time that was actually spent for m_2 is assumed as time for m_3 .

Considering the correction, the algorithm showed one more downside. As mentioned in 2.2.2, tutors can directly close a question without triggering an opening event. The reason is that the value of the credits is set by default to the maximum possible and the correctors can just "confirm" it. The problem comes from the fact that the time tracking methodology assumes that each time span is the time between an opening and a closing event. This means that when for one question only closing events occur, the calculated time interval for it is 0.

All of these concepts lead to the conclusion that an adaptation or a complete new implementation of the algorithm would be very advantageous for the future. Because of its possible inaccuracy, we also decided to not implement the previously discussed

Time left artifact (II) at this point. Showing inaccurate times to student might increase their frustration. We leave these points as possible future research topics (7.1).

The second artifact consists of two feedback elements. The first one is a web page visualizing worst answered multiple choice questions for each preparation part of each topic in the courses. The second one is a web page visualizing worst answered input questions for each exercise part of each topic.

Both pages visualize all questions in the corresponding prelab/lab instance and a table (Figure 5.3) with statistics for those questions. The tables are ordered according to the order in which the questions occur in the instance. Considering the time analysis artifact, we display a lot of information on the new statistics page. This is why it was not convenient to display the questions as well. Instead, we chose to embed links. The current visualizations are compact and allow including the questions' contents as well. (Diversity 1.3)

The implementation and visualizations of this artifact are simple, straightforward and are expected to fulfill their purpose in improving the learning process of the ilab participants. (Simplicity 1.1)

The third artifact consists of one feedback element. Namely, a web page visualizing additional multiple choice statistics for each prelab (Figure 5.6). Those statistics are structured in pie charts and plain text. More specifically, the plain text shows the absolute number of times each multiple choice answer has been chosen, and the pie chart shows the distribution of 'clicks' for all answers in percentage. (Diversity 1.3)

The pie chart makes "preferred" answers immediately recognizable. (Simplicity 1.1) When exact numbers are needed, they are also present right next to the chart. This is a sufficient solution for recognizing by which concrete answers did problems occur.

Chapter 7

Conclusion

Chapter 2 of this Bachelor's thesis researched best practices for creating a good learning process and identified feedback as one of the most important ones. It discussed different requirements for feedback and purposes of different feedback elements. Chapter 3 compared four eLearning platforms and the feedback features they offer.

On base of this research, we made the decision to design and implement three additional feedback elements for the eLearning labsystem platform, which this thesis aims to improve. We implemented a visualization displaying time analysis of each lab topic. This visualization has different levels of detail and reveals time related problems. Furthermore, we created visualizations showing results achieved in different parts of a topic. They indicate problems, which can be based on insufficient self-preparation, misunderstanding of a concept or non-optimal content structure.

In my personal opinion, the newly implemented feedback elements are sufficient solutions, which help to make the learning process more transparent and to improve it.

Limitations are, of course, present. They concern the algorithm on which the time analysis is based. They were discussed in detail in Chapter 6 and are a part of the topics possible future work can be based on (7.1).

7.1 Future work

One possibility for extension of this thesis would be the implementation of the features offered by Coursera, edX and Moodle, which we recognized as missing in the labsystem in Chapter 3. One example is a chat.

Another possibility would be to implement the two artifacts from our initial ideas list 2.6. One of them is the feedback element "Emotional feedback" (V). The other one is the Time left element (II).

We discussed (V) as a further method that can help the recognition of problematic/most liked questions. We even presented a possible design of such element (4.3).

We presented a possible design idea for the Time left as well (4.1.2). However, the first step that should be taken under consideration when implementing this artifact would be to adapt the existing algorithm that it is based on. Another possibility would be to implement a completely new one, considering the notes we left in the Evaluation chapter (6).

An improvement of the time tracking algorithm, which finds solutions for the problems described in (6), would be an advantageous future work topic on its own. Even if it is then only used to resolve the existing problems, without being used for the implementation of further features.

Another possible future topic would be the implementation of features, which make the time analysis easier and more precise. For example, buttons "pause", "revise" and "end". The students can use them when making big pauses, which should not be included in the time needed for an element, or when finishing a prelab. Such elements will be helpful for the implementation of more precise time tracking algorithms.

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