



iTalk2Learn  
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## Deliverable 3.4.1

### Initial report on methods and prototype for intuitive interaction interfaces for robust learning

30<sup>th</sup> April 2014

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**Project full title:** Talk, Tutor, Explore, Learn: Intelligent Tutoring and Exploration for Robust Learning



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0.6	24/04/2014	Pre-final version



### **D3.4.1 Initial report on methods and prototype for intuitive interaction interfaces for robust learning**

## **Executive Summary**

Work Package 3 (WP3) envisions to provide the technical means by which more exploratory, conceptually-oriented learning activities can be integrated with the rest of the platform and enable research on the role of the different modalities of speech and direct manipulation as well as multiple and alternative representations in learning elementary mathematics (and particularly the domain of fractions as selected by the consortium).

This deliverable reports on methods and technologies for creating intuitive interfaces for robust learning with a focus on following activities:

1. behavioural interaction interpretation for enhanced learner understanding
2. speech production
3. GUI framework for exploratory learning activities in elementary mathematics
4. harmonisation of GUIs and enhancements on usability of the iTalk2Learn platform

### **D3.4.1 contributes to MS61 - Initial Intelligent learning support platform for intuitive and robust learning"**

The structure of the deliverable is as follows:

Section 1 describes general objectives of the project and of WP3, together with a definition of intuitive interaction interfaces in the context of iTalk2Learn. Moreover, it presents goals and objectives for the four activities presented above, with references to WP1 and WP5.

Section 2 describes the progress at M18, showing the results, but also the risks and contingency actions involved. In particular, Fractions Lab - the GUI framework for exploratory learning activities designed and developed in the project – is extensively presented.

Section 3 draws the conclusions and outlines next steps with regards to the four activities that constitute WP3.



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### **List of Abbreviations**

UHI	University of Hildesheim
IOE	Institute of Education, University of London
TL	Testaluna SRL
RUB	Ruhr-Universitaet Bochum
BBK	Birkbeck College - University of London
Whizz	WHIZZ Education Limited
SAIL	SAIL Labs Technology AG
WP	Work Package
ELE	Exploratory Learning Environment
iT2L	iTalk2Learn acronym
GUI	Graphical User Interface
UI	User Interface
HCI	Human-computer interaction
VUI	Voice-user interface
SVM	Support Vector Machine



## 1. Introduction

iTalk2Learn is a research project implemented in the context of the 7<sup>th</sup> EU framework programme. The project will perform interdisciplinary, cutting-edge research in a multidisciplinary team with members from fields as diverse as artificial intelligence/machine learning, user modelling, intelligent tutoring systems, and natural language processing, as well as educational psychology and mathematics education. The specific objectives of italk2learn are to:

1. provide an open-source platform for intelligent support systems integrating structured practice and exploratory, conceptually-oriented learning
2. provide state-of-the-art and highly innovative reference implementations of plugins for the platform that could be used in a wide range of application domains
3. promote our understanding of the role of the different modalities of speech and direct manipulation of multiple or alternative representations in learning elementary mathematics through digital technologies
4. conduct a summative evaluation of activities and support features generated by our intelligent learning support platform

The implementation of these blocks of activities is distributed across Work Packages (WP) which are listed below:

WP number	WP name	Lead beneficiary
1	Robust Learning in Elementary Mathematics	IOE
2	Adaptive Intelligence for Robust Learning Support	UHI
3	Intuitive Interaction Interfaces for Elementary Mathematics	TL/SAIL
4	Deployment and Integration	BBK
5	Data Collection and Evaluation	RUB
6	Dissemination and Exploitation	Whizz
7	Project Management	UHI

In reference to the objectives of the iTalk2Learn project, WP3 envisions to provide the technical means by which more exploratory, conceptually-oriented learning activities can be integrated with the rest of the project (c.f. Objective 1) and enable research on the role of the different modalities of speech and direct manipulation as well as multiple and alternative representations in learning elementary mathematics (c.f. Objective 2). This will occur in the mathematical domain of fractions. The project selected fractions as the target domain because of the widely acknowledged difficulty



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that students have in learning fractions and the richness fractions afford with respect to different representations and interpretations.

WP3 is focused on the design and development of:

- i. intuitive interaction interfaces
- ii. an advanced behavioural interaction interpretation system for enhanced learner understanding

As referred to in greater depth in D3.2, the “intuitive interaction” theme has been quite largely debated during the last decades in literature and in academic papers (c.f. Blackler & Hurtienne, 2007). Thus there are several definitions, but in a lot of cases divergent from one other. In short, the common denominator of all these definitions is to recall the semantic sphere of the terms “usability”, “ease of use” (Preece et al., 1994) and “familiarity” (Raskin, 1994).

Based on the overarching goal of creating a web-based platform (as outlined in D4.1) that allows students focusing on learning activities supported by direct manipulation user interfaces (UIs), voice interaction and intelligent components for providing feedback and recommendations, in iTalk2Learn **the term ‘intuitive interaction’ refers to:**

- a. The opportunities afforded by the Exploratory Learning Environment (ELE) through familiar, interactive representations of fractions that capitalize on students’ prior knowledge or experience and are simple and easy to use.
- b. The Voice-User Interface (VUI) that should, in principle, enable a more natural means of interaction compared to just keyboard and mouse interaction.

With respect to the above definition, WP3 is devoted to design and development of innovative and intuitive interaction interfaces for Elementary Mathematics, including voice and direct manipulation user interfaces.

The achievement of this objectives implies the provision of:

- Speech production and speech recognition software (to enable a more natural interaction of children with the system).
- A Graphical User Interface (GUI) framework for exploratory learning activities in elementary mathematics, referred from now on as Exploratory Learning Environment (ELE).
- Coherent visual interface and look and feel to the iTalk2Learn platform.

Due to the importance that speech recognition has in iTalk2Learn, despite being part of the intuitive interaction interfaces, in the proposal phase (and thus in the DoW) it has been decided to dedicate specific deliverables to the tasks pertaining to such technology (namely D3.1 delivered at M6, D3.3.1 due at M18 and D3.3.2 due at M36). For this reason, in this deliverable we will not





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describe activities and results related to speech recognition.

#### **Relationship to the project and contribution to the overall goals and vision**

The activities and results described in this deliverable contribute to the project's goals and vision by:

- i. Developing Fractions Lab, an ELE created from scratch in the project based on the design described in D3.2. Creating the ELE ad hoc, rather than adopting something available on the market, allows the extraction of targeted user data needed for various components of the system (e.g. task sequencer, task-dependent support). It also allows, through WP1, the design of specific tasks to be used in studies. Finally, it allows for integration of a task-dependent support system that provides feedback to students while interacting with Fractions Lab.
- ii. Facilitating (a) task sequencing and (b) task-independent support within iTalk2Learn platform. Such activities belong to T3.4, and started with the identification of features, classes instances and methods along with state-of-the-art, which could be used for an automatic affect recognition.
- iii. Developing a speech production component to speak aloud both to describe the tasks at hand and to support students' interaction.
- iv. Creating a coherent visual interface of the various user facing components of the system. This involves applying best practices and guidelines of GUIs design by taking into account the general design and technical limitations of the iTalk2Learn platform.

#### **Key achievements at M18**

At M18 WP3 has achieved:



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- **Advanced behavioural interaction interpretation for enhanced learner understanding:** identified features, classes, instances and methods to apply emotion and affect recognition methods.
- **Speech production:** speech production is working on the iTalk2Learn platform as planned. Students now receive spoken feedback and guidance while engaging with the platform.
- **GUI framework for exploratory learning activities in elementary mathematics:** released a complete version of Fractions Lab to be integrated with the iTalk2Learn platform (WP4). This is the result of development activities (T3.6) based on design described in D3.2.
- **HCI harmonisation and GUI enhancement:** designed a set of GUI proposals to accomplish the needs of usability and harmonisation of the platform. Such proposals, besides having the same features and technical characteristics, show a different look and feel. They will be reviewed by the consortium and the one who will reach a consensus upon will be implemented in following period.

## 1.1 Goals and objectives

This section outlines the goals and objectives that guided (and will guide) partners in the activities characterizing intuitive interactive interfaces in the context of iTalk2Learn.

### 1.1.1 Advanced behavioural interaction interpretation for enhanced learner understanding

In T3.4 (behavioural interaction interpretation for enhanced learner understanding), started in month 16, the behaviour of students shall be analysed by automatic emotion and affect recognition applied to speech input from the students. The output of this approach shall be used for two different parts of the iTalk2Learn system: (a) for supporting performance prediction and sequencing of tasks, (b) for task-independent support. Traditionally, the performance prediction and sequencing in intelligent tutoring systems is done using logged information about the performance of the student in former exercises. UHI addresses (a) and aims at enhancing the way information is used for performance prediction and sequencing (see WP2 and D2.2.1) by analysing additionally the speech of a student interacting with the system while solving tasks. BBK addresses (b) and aims at creating task-independent support depending on the emotion or affective state of a student while solving tasks (see D2.2.1).



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#### **1.1.2 Speech production**

Intuitive speech-based interaction in the context of iTalk2Learn requires both speech recognition to understand what students say and speech production (i.e. synthesis) to allow the computer to talk to students. In particular, the goals of the speech production component of iTalk2Learn are to speak aloud both to describe the tasks at hand and to support the students' interaction.

Description of tasks: tasks are presented to students with a short description (e.g. "create a fraction that is equivalent to the fraction on the screen"), these descriptions are shown both in written text and spoken aloud to help student with weaker reading skills.

Support: support is offered in the context of tasks when students are blocked or show lack of understanding; support can be provided in non-textual form (i.e. highlighting some component on the screen), on text+speech form, or on purely-spoken form. In the second case, support is provided in text and is also read aloud by the speech production component to help student with weaker reading skills. In the third case, support is provided only in spoken form (i.e. no text), maybe combined with some form of non-textual feedback like highlighting a component. This is the case with some forms of feedback that are designed to be non-interruptive; examples include the use of prompts and nudges to encourage students to think aloud as they interact with the system or to express how they feel.

As of M18 various versions of speech production have been tried in the various studies with the system. That included a male voice of the Festival library<sup>1</sup> and a British female voice from Google text-to-speech API. Although the emphasis in iTalk2Learn is not in doing research with respect to the speech production system, designing intelligent educational systems is a complex endeavour that requires a holistic approach of the interaction with the student and that includes the speech production component to give the appearance of a proper system. As such we are soliciting feedback from students and as of M18, the students suggested improvements that could be made to the system. In earlier trials the male Festival voice was not so welcomed, reporting it to be very brusque when they were being reprimanded. The Google English female voice was more acceptable but still some students felt it had a sarcastic tone, particularly for feedback such as "well done". In subsequent trials under WP5 this will be investigated further.

#### **1.1.3 GUI framework for exploratory learning activities in elementary mathematics (ELE)**

The main goal of this activity (T3.6) was the implementation of the Fractions Lab, the ELE designed expressly for iTalk2Learn. In order to contextualize the description of the activities and results obtained, we summarize hereby the approach followed to design Fractions Lab and the guidelines that drove development activities (more details available in D3.2).

The design of an ELE usually opens up a range of possible options that impact in very different ways on the final outcome. The educational background, various skills and knowledge of the members of

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<sup>1</sup> <http://www.cstr.ed.ac.uk/projects/festival/>



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the design team allowed us to reach into several sources (e.g. social constructionism, cognitive load theory, instructional design and mathematics education) and to evaluate things from different points of view.

Thus the design of Fractions Lab became strictly dependent on the critical analysis that derived from literature, from the analysis conducted and from previous experience of the partners in designing and evaluating ELEs directly in the classroom (this concerns particularly IOE). As a natural consequence it has been decided to follow a principled design approach.

The process has led to the identification of a set of 5 Design Drivers:

- The design of the ELE should embed a 'reconstructive' approach to learning, involving a range of mental objects/processes.
- The design of the ELE should utilise a variety of representations and interpretations of fractions and support students in making connections between them.
- The design of the ELE should utilise a variety of representations and interpretations of fractions (large use of pictorial representations such as area, number line, set of objects and liquid measures.
- The design of the ELE should motivate students to engage with fractions.
- The design of the ELE should use a familiar metaphor to guide students to act in a desired way (the designers have used a 'desktop' metaphor – that recalls Windows or Macintosh operating systems - with 'trash', 'recycle', 'folders', and 'files' etc. to enable students to recognize certain features in a simple way.
- The design of the ELE should provide access tools to support students' activities that, whilst essential to completing the task, would normally detract from the completion of the task if undertaken manually.

In addition to these Design Drivers the design team identified several Design Conjectures that arise from critical analysis and experience of existing related educational software and provide the means of raising requirements:

- Provide a wide range of interaction for students:
  - a. dragging and dropping representations
  - b. changing the size and colour of representations
  - c. choosing and using tools to manipulate representations
  - d. seeing or setting dynamic dependencies between representations
  - e. setting and changing a fraction's value in a few steps



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- Provide a wide range of feedback to students
  - a. integrated (i.e. by the design of the environment e.g. linking representations)
  - b. explicit (i.e. resulting from an action)
  - c. non-interruptive (e.g. on request or on appropriate occasions)
  - d. co-located with objects in the environment (e.g. focus or pointing to crucial aspects) and
  - e. enables student freedom to choose the aspect they receive feedback upon

#### 1.1.4 HCI considerations and GUI harmonisation and enhancements

The harmonization and enhancement of the GUIs of the iTalk2Learn platform aims to create a coherent visual interface of the various user-facing components of the system. This means streamlining the GUIs in order to allow users to focus their attention not on learning how to use the tools, but, on the contrary on the subject matter. The goals for M18 were:

- To collect requirements and to get to a better understanding of the envisaged UIs and means of interaction with the platform.
- To make a technical analysis of the affordances of the underlying technologies in order to define a strategy for allowing different teams to work both on the development of the platform and on the GUIs in a separate and parallel way.
- To generate a certain number of GUIs proposals to be analysed and selected by the consortium towards future implementation.

## 2. Progress (*at M18*)

This section presents the progress of activities of WP3 at M18, with a particular focus on Fractions Lab, that reached a complete state of development at this stage of the project.

### 2.1 *Behavioural interaction interpretation for enhanced learner understanding*

Before an automatic emotion and affect recognition approach can be applied, three main aspects should be taken into account:

1. what kind of features shall be used
2. what kind of classes shall be used



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3. which instances shall be mapped to features and labelled with the class labels

After deciding which features, classes and instances shall be considered, emotion and affect recognition methods can be applied to those input data. In the following subsections features, classes and instances which UHI and BBK will use for T3.4 are presented and state-of-the-art methods are mentioned.

#### **2.1.1 Features**

The first step before applying automatic emotion and affect recognition is to identify useful features for this process. For the purpose of recognising emotions and affect in speech two different kinds of features can be used (Schuller et al., 2011): acoustic and linguistic features. Furthermore, it is also interesting to distinct linguistics, like n-grams and bag-of-words, from disfluencies, such as pauses or fillers.

If linguistics features are used, a transcription or speech recognition process has to be applied to the speech input before emotion and affect recognition can be conducted. Subsequently, approaches from the field of sentiment classification or opinion mining (Sadegh., Ibrahim, & Othman, 2012) can be applied to the output of this process. However, the methods of this field have to be adjusted to be applicable to speech instead of written statements. The advantage of using linguistic features is they are well established and one can focus on the methods for emotion and affect classification.

As mentioned above, another possibility for features is to use disfluencies features has been done for expert identification (Worsley & Blikstein, 2011), (Morency et al., 2013), (Luz, 2013). The advantage of using such features is that instead of a full transcription or speech recognition approach only a disfluencies identification has to be applied before. That means that – in the case of speech recognition – one does not inherit the error of the full speech recognition approach. Furthermore, these features are independent from the need that students use words related to affects. For using this kind of features one has to investigate which particular features are suitable for the special task of emotion and affect classification in intelligent tutoring systems.

UHI and BBK will investigate both kinds of features - linguistics features, as well as disfluencies features.

#### **2.1.2 Classes**

The second step before applying automatic emotion and affect recognition is the definition of the classes corresponding to emotions and affective states, which shall be recognised by the used emotion and affect recognition approach.

For the task-independent support BBK focuses on emotions that arise from a learning situation. The emotion detector is based on the achievement emotions described in (Pekrun, 2006) as well as emotions that were detected in the Wizard of Oz studies that will be described in D5.2. The



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following five emotions are included in the task-independent support: enjoyment, surprise, confusion, frustration and boredom. UHI plans to use the student behaviour information gained from speech for performance prediction and sequencing of exercises. In (Krohn-Grimberghe et al., 2011) and (Schatten & Schmidt-Thieme, 2014) the theory of Vygotsky's Zone of Proximal Development (Vygotski, 1978) was used for performance prediction and sequencing to keep the student in flow. That means that the goal is to neither bore the student with too easy tasks nor to frustrate him/her with too hard tasks, but to keep him/her in the Zone of Proximal Development. Accordingly, UHI plans to use the output of the automatic emotion and affect recognition to get an answer to the question „Was this task too easy, too hard or appropriate for the student?“. In other words, UHI wants to find out if the student was under-challenged, over-challenged or in the flow. However, the mapping between confusion, frustration, boredom and under-challenged, over-challenged is not unambiguous as one can infer e.g. from the studies mentioned in (Woolf et al. 2009). Hence, UHI plans to use instead of the emotion classes three other classes for supporting performance prediction and sequencing: under-challenged, over-challenged and flow.

#### **2.1.3 Instances**

The third step before applying automatic emotion and affect recognition is deciding which instances shall be mapped to features and labelled with the class labels. For task-independent support information are needed about the affective state of a student while the student tries to solve a task, to be able to give him/her immediate support. For performance prediction and sequencing, on the other hand, at the end of a task the information if the task overall was too easy, too hard or appropriate for the student is needed, as by means of that information the next task shown to the student shall be chosen. Hence, the instances for task-independent support are utterances spoken by the student while solving a task, and an instance for performance prediction and sequencing is the whole speech input of a student for one task.

#### **2.1.4 Methods**

The possible methods for automatic emotion and affect recognition depend on the kind of features used as input. As mentioned above, we distinguish two kinds of features: linguistics features and disfluencies.

Linguistics features are gained by a preceding speech recognition process and can be processed by methods coming from the areas of sentiment classification and opinion mining (Sadegh, 2012). Especially methods from the field of opinion mining on microposts seem to be appropriate if linguistics features are considered. State-of-the-art methods in opinion mining on microposts for instance use methods based on optimisation approaches (Hu et al. 2013) and Naive Bayes (Saif et al. 2012).

The process of gaining disfluencies like pauses is different to the full speech recognition process. For extracting for instance pauses usually an energy threshold on the decibel scale is used as in (Luz, 2013) or a support vector machine (SVM) is applied for pause classification on acoustic features as in (Qi F. et al., 2011). For extracting fillers on the other hand one could use methods





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from the field of phoneme recognition like the hybrid neural network approach which we proposed and investigated in (Janning, R et al., 2014).

Appropriate state-of-the-art methods for automatic emotion and affect recognition on disfluencies features are - as proposed in (Schuller B., 2011) and (D'Mello S.K., 2008) – classification methods like artificial neural networks, SVMs, decision trees or ensembles of those.

## **2.2 Speech production**

Speech production is working in iTalk2Learn as of M18, as planned.

After trying several technologies, we are relying on Google's speech production engine, which is freely available by using HTTP requests. The HTTP request is a GET request with the following parameters:

- q - the query string to convert to audio
- tl - translation language, e.g.ar for Arabic, or en-us for English, ie - encoding format (default UTF-8)

[http://translate.google.com/translate\\_tts?ie=UTF-8&q=hello&tl=en\\_gb&total=1&idx=0prev=input](http://translate.google.com/translate_tts?ie=UTF-8&q=hello&tl=en_gb&total=1&idx=0prev=input)

As a result of this request, the server returns a chunk of audio that the iTalk2Learn platform can embed on a HTML audio player. An HTML5 audio player provides methods, properties, and events allow you to manipulate <audio> and <video> elements using JavaScript. The API to reproduce audio is quite simple to use; the two main methods are load() and play(), which respectively re-load the audio/video element and start playing the audio/video.

## **2.3 The GUI framework for exploratory learning activities in elementary mathematics: Fractions Lab**

The design of Fractions Lab has not been straightforward, but implied a back and forth process, whose constituents were: requirements gathering, development of features and feedback from partners, teachers and students. In practice IOE and TL shared powerpoint presentations, drawings and had online meeting to clarify the features of the software to come.

Although a static document is not the most appropriate means to illustrate Fractions Lab, the following pages provide a description and several snapshots of its features and peculiar functionalities.

For the purpose of trying it, a direct link to a working version of Fractions Lab is available:





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<http://link.lkl.ac.uk/FractionsLab>

This has been used for the purposes of improving the design and undertaking formative evaluation studies with respect to Fractions Lab (as mentioned in D5.1). The complete and final version will be available on iTalk2Learn platform.

#### 2.3.1 Layout

Fractions Lab is an ELE which provides tools to experiment and test, apparently unguided, the knowledge and the experience of students on fractions. **Fractions Lab** allows the students to

- visualize fractions
- discover the relation between various fractions and their relation to the whole
- learn operations in a simple way

After launching Fractions Lab the user can see a simple Start page. The start button bring students into the learning environment.



*Figure 1: Start Page*

The layout of Fractions Lab is defined by five main components:



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- The **experimental area [A]** has been designed as a blackboard where students can experiment with fractions and display and manipulate them by carrying out various operations.
- The **representations area [B]**, on the right, offers different representation of fractions to be used in the experimental area.
- The **operations area [C]**, at the top, gives students a means of verification for different operations with fractions.
- The **feedback area [D]**, at the bottom, provides different type of feedback and gives advice to the student.
- The **bin area [E]**, at the upper left, can be used to delete the representations that are no longer needed.

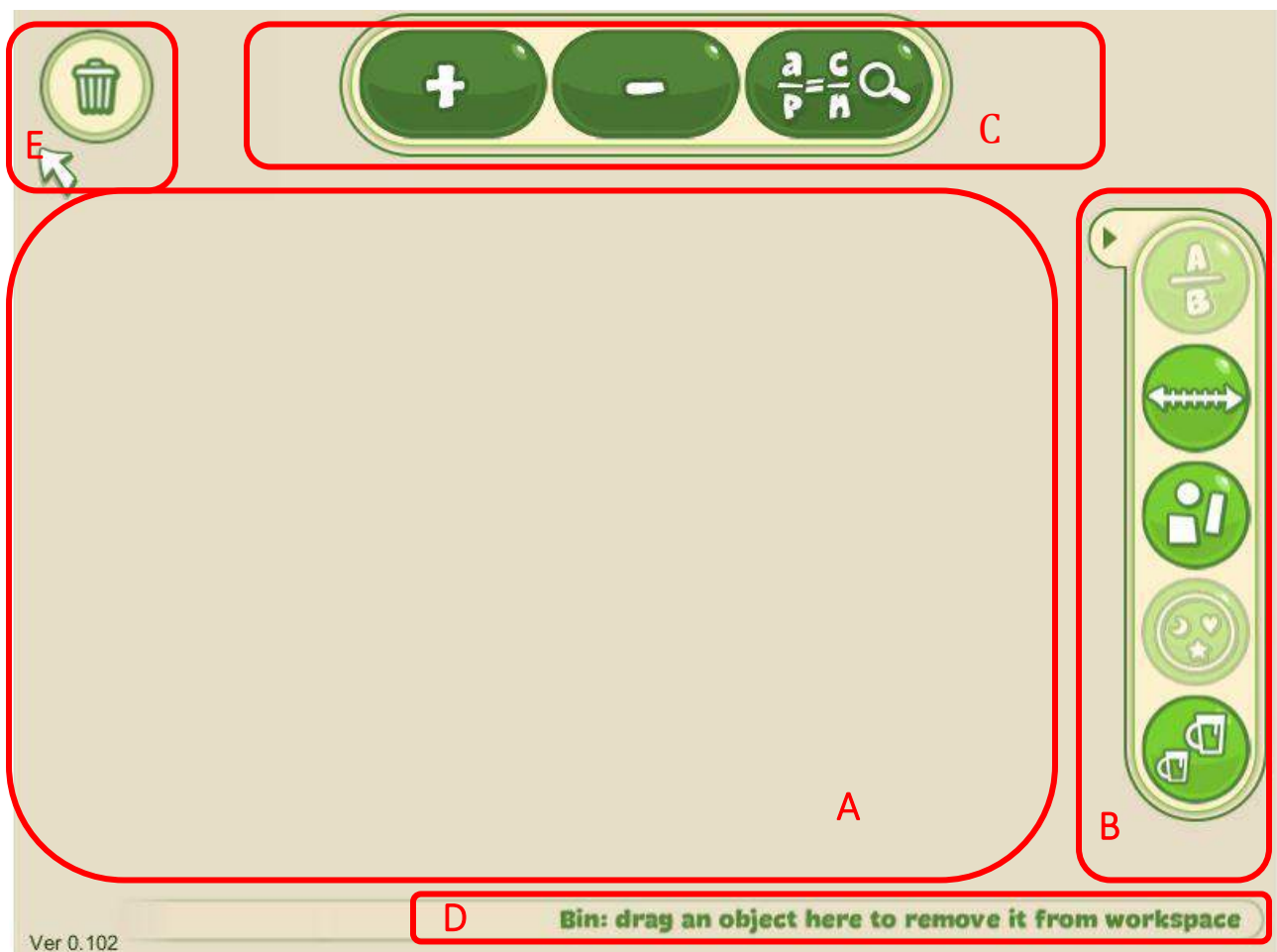
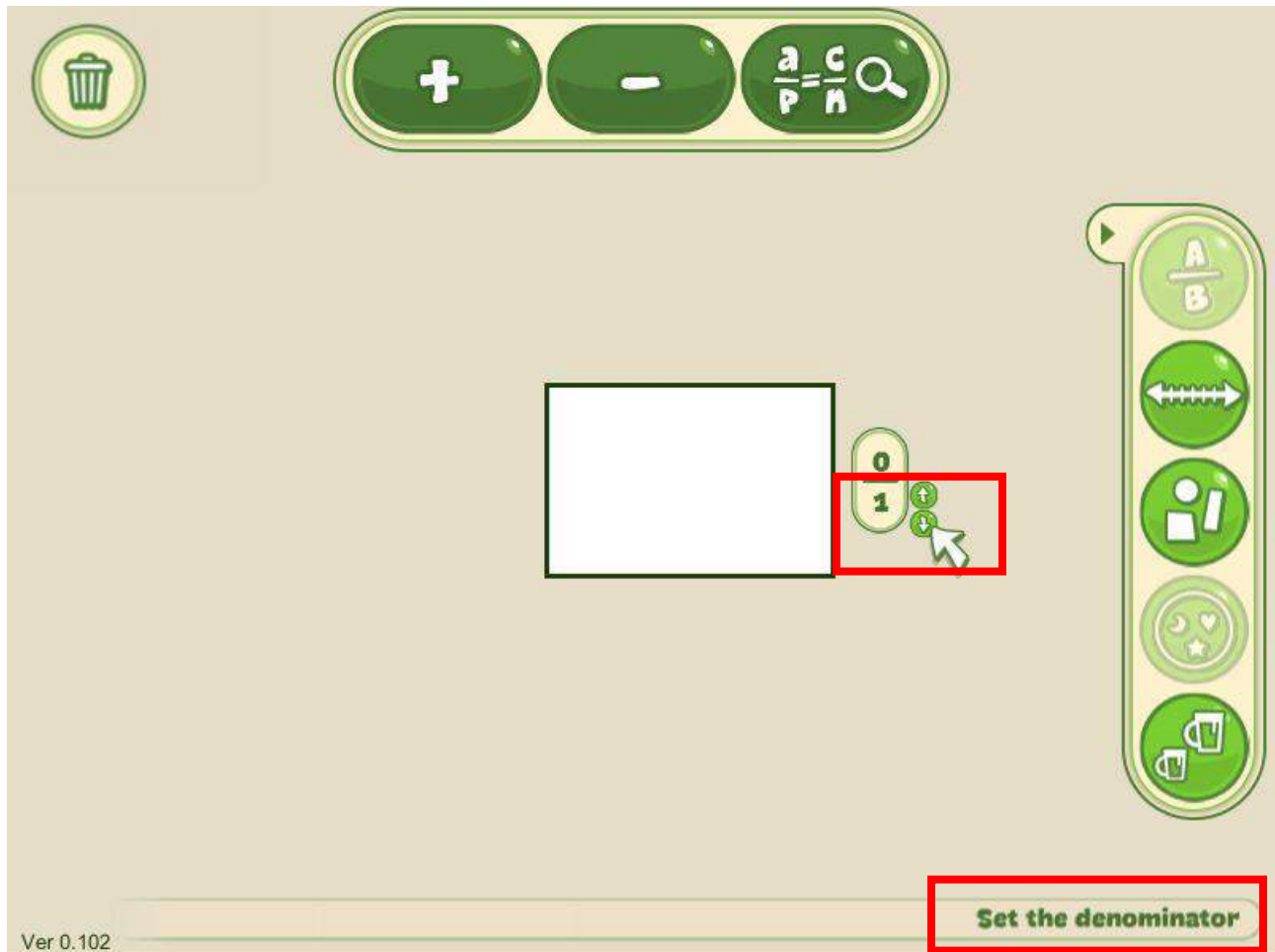


Figure 2 –The layout

### 2.3.2 The experimental area [A]

Students can select one of the various representations (from [B]) and manipulate it using tools available by recalling a contextual menu (with right click of the mouse).

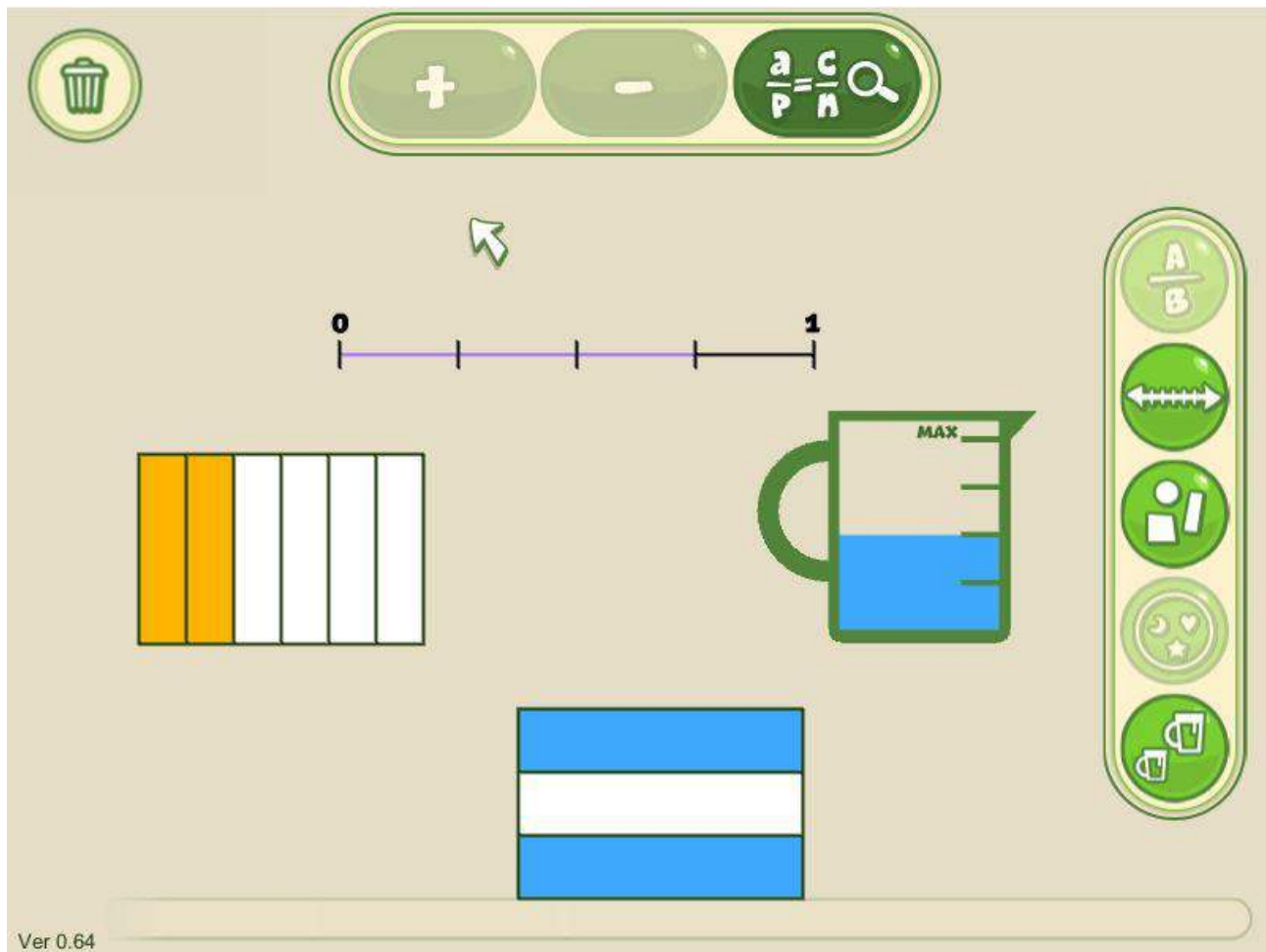
After choosing one of the representations, the first thing to do is to set the denominator of the fraction. Moreover, accordingly with the design, the system only supports non-negative real-valued fractions.



*Figure 3 –Choosing representation and setting the denominator*

The numerator can be set in two different ways: by clicking on the arrows at the right of the representation or simply by clicking on the representation itself.

More than one fraction can be displayed and more than one kind of representation can be used at a time.



*Figure 4 – Fractions Lab allows to display more representation at a time*

#### 2.3.3 The representation area [B]

Following the design guidelines, the representation area provides students with the possibility to choose between five types of representations available:

- Symbol
- Number lines
- Shapes
- Sets
- Liquid Measures

As a general rule, the denominator is represented by the number of sections, in which the figure is divided (of course the way in which the denominator is displayed varies according to the type of representation that the user has selected).

The numerator, on the contrary, is indicated by the number of colored sections of the representation.



*Figure 5 – The representation area*

#### 2.3.4 The operations area [C]

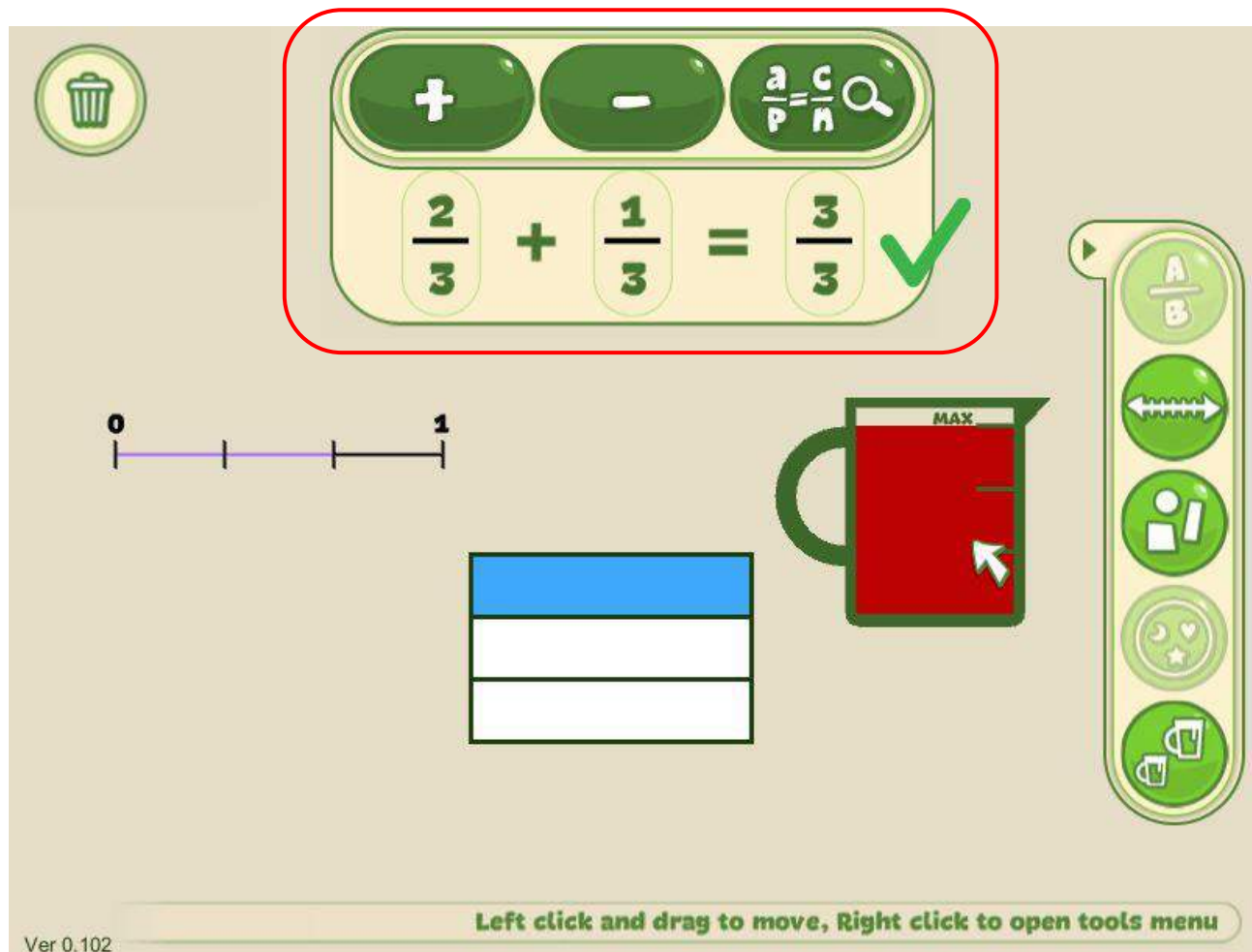
The operations area has been designed to stimulate students to understand addition, subtraction and equivalence of fractions.

Three buttons are available here: plus, minus, equal. By pressing one of these buttons the student can check the result of the corresponding operation.

The system doesn't provide results automatically, on the contrary the student is required to do the operations by himself and then a green check or a red cross will be displayed.

Therefore, the student works on fractions in the experimental area and if, for instance, he/she has to verify the sum of  $\frac{3}{4}$  and  $\frac{1}{4}$ , he/she has to create representations for the two addends and also the result. Subsequently he/she can drag and drop the three representation in the operations area to verify the result, the system indicate if the equation is true or false.





*Figure 6 - The operations area*

#### 2.3.5 Tools

When the student clicks with right mouse on the visualized fraction, he/she can see a menu that can be used to operate upon the representations.

This is consistent with the aim of providing a wide range of interactions, actions to be performed and possibility to manipulate fractions.



**Figure 7 – Tools menu**

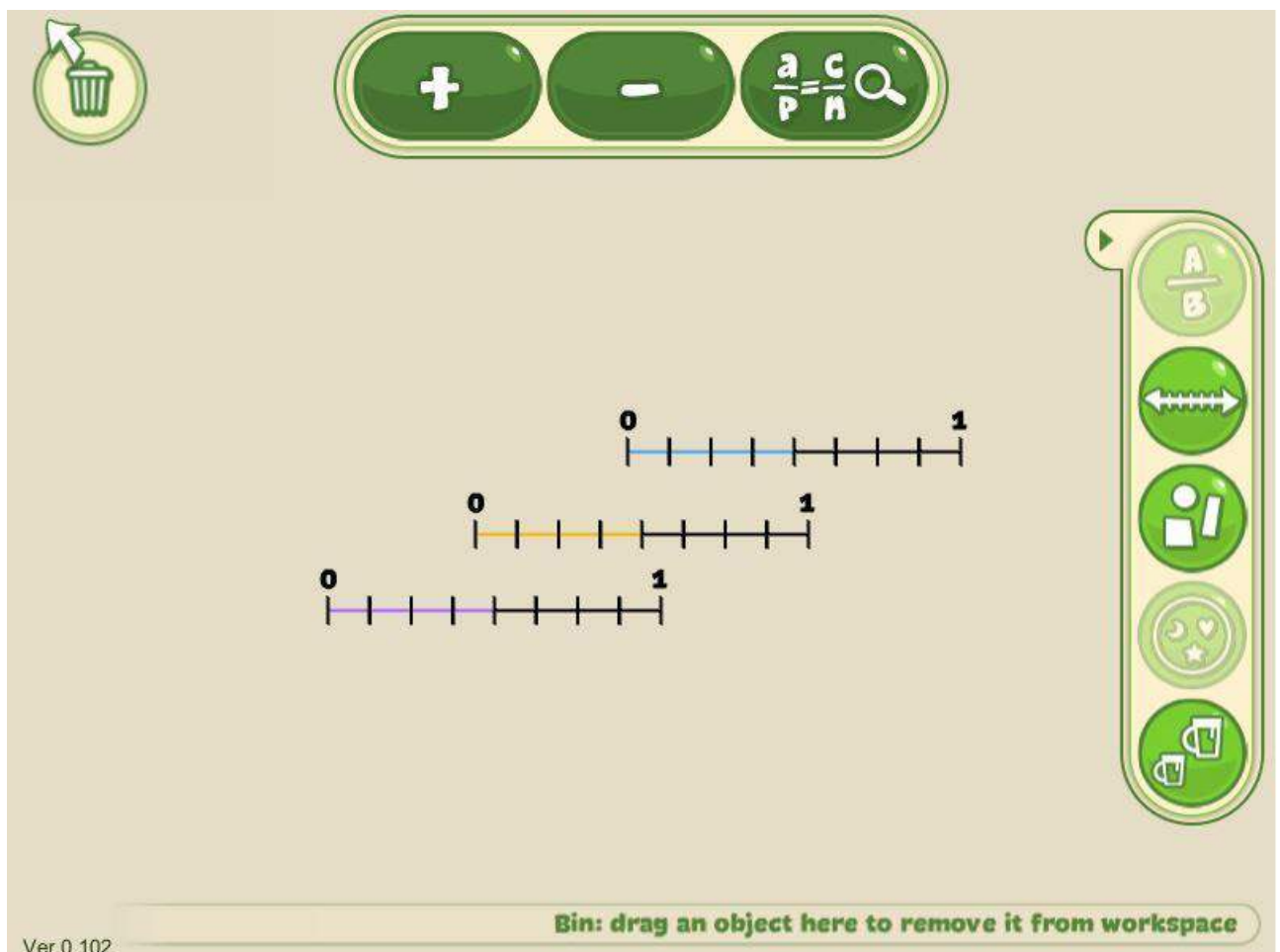
By means of tools students can:

- change fraction denominator or numerator (the numerical representation of the fraction is again displayed next to the graphical representation)
- change size of the representation
- change colour of the sections representing the numerator of the fraction
- create a copy of the representation
- “use” a representation. This tool extract the numerator from the displayed fraction. The parent fraction is frozen, and the user may, at this point, use the numerator to do several operation which are finalized to let him better understand addition and subtraction. Right clicking opens the *actions menu* to access these functions (see next paragraph)



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- show/hide the symbol that shows numerator and denominator
- “partition” a representation. This tool helps students to acquire the idea of equal shares and of combining and recombining fractions. Different graphic elements (e.g. vertical lines in a horizontal rectangle) will mark the fraction which originated the partition and the partition itself.



*Figure 8 - The yellow and cyan numbered lines obtained with “copy” tool (from purple one)*



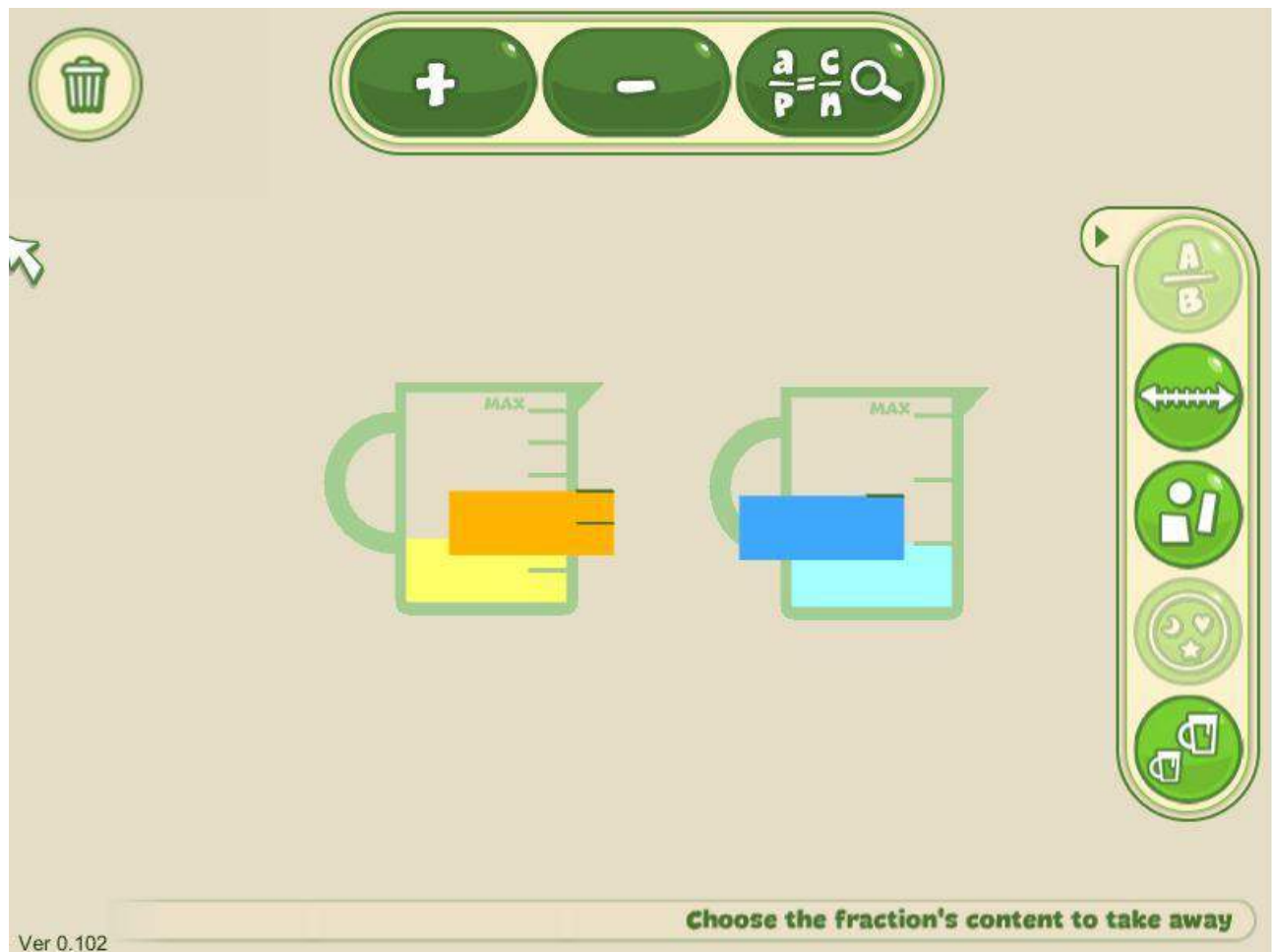
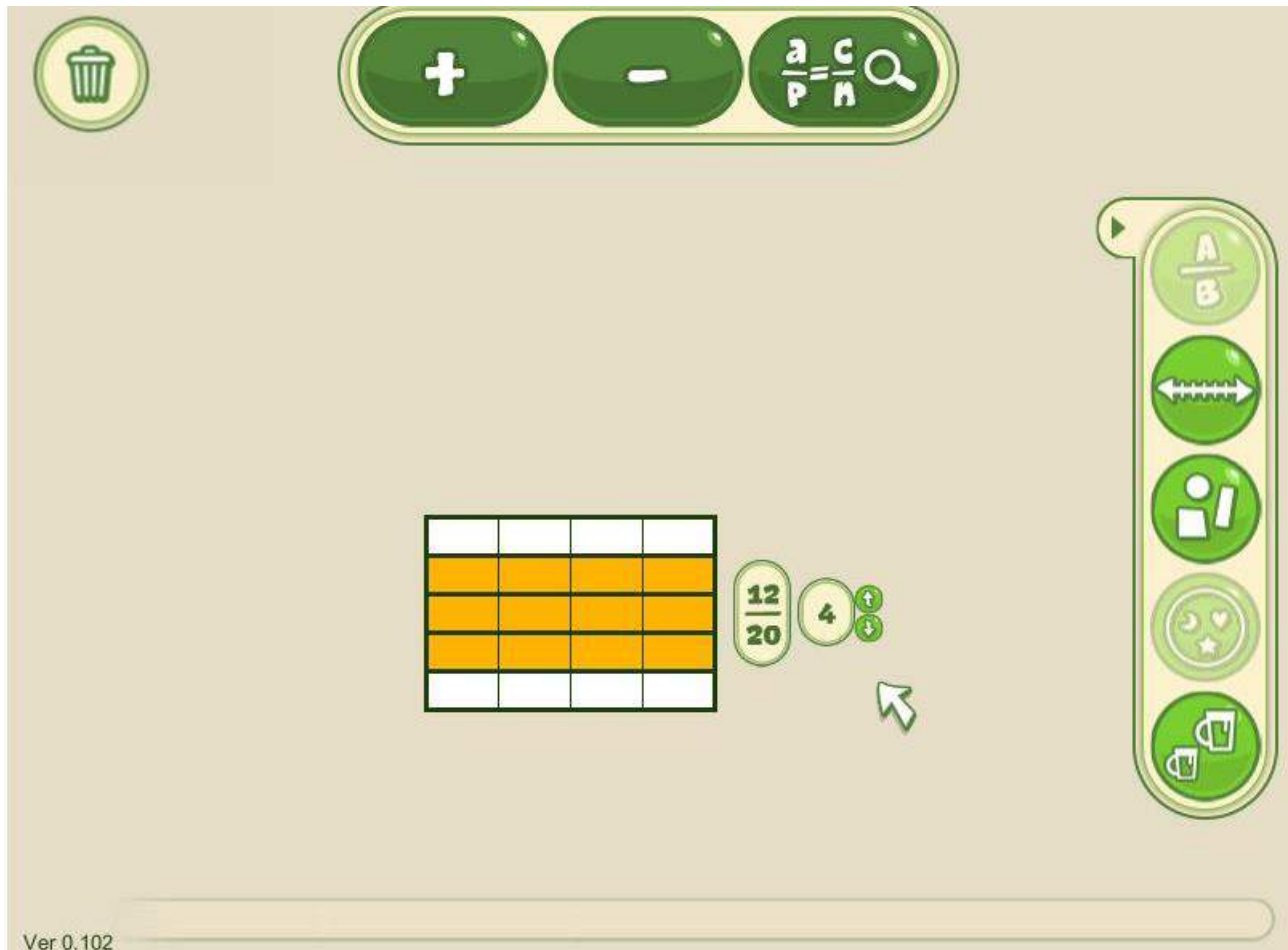


Figure 9 - The "use" tool



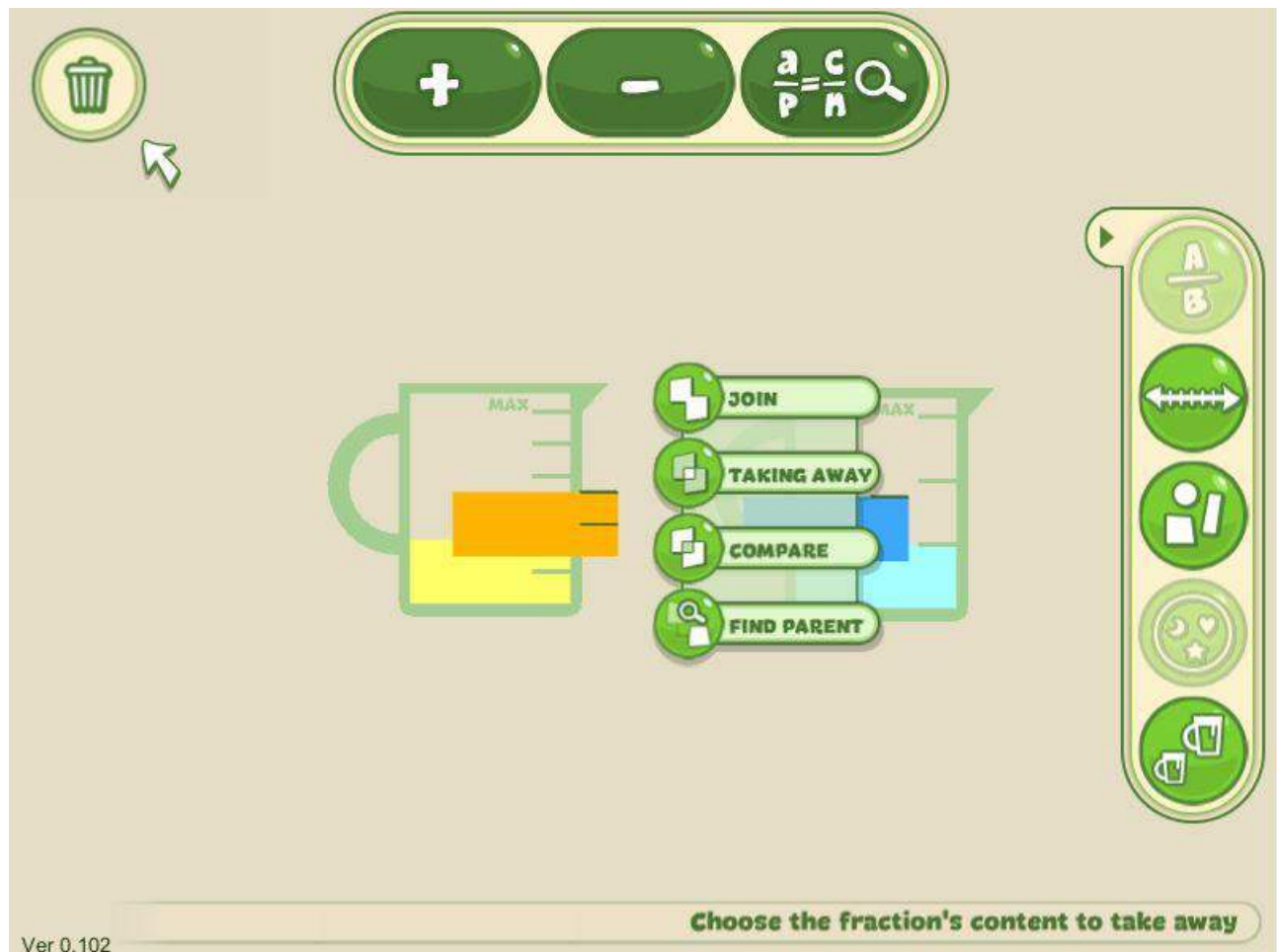
*Figure 10 - The “partition” tool*

#### 2.3.6 Actions

Once a string is extracted (use command) from the representation of the fraction, the student can access the actions menu.

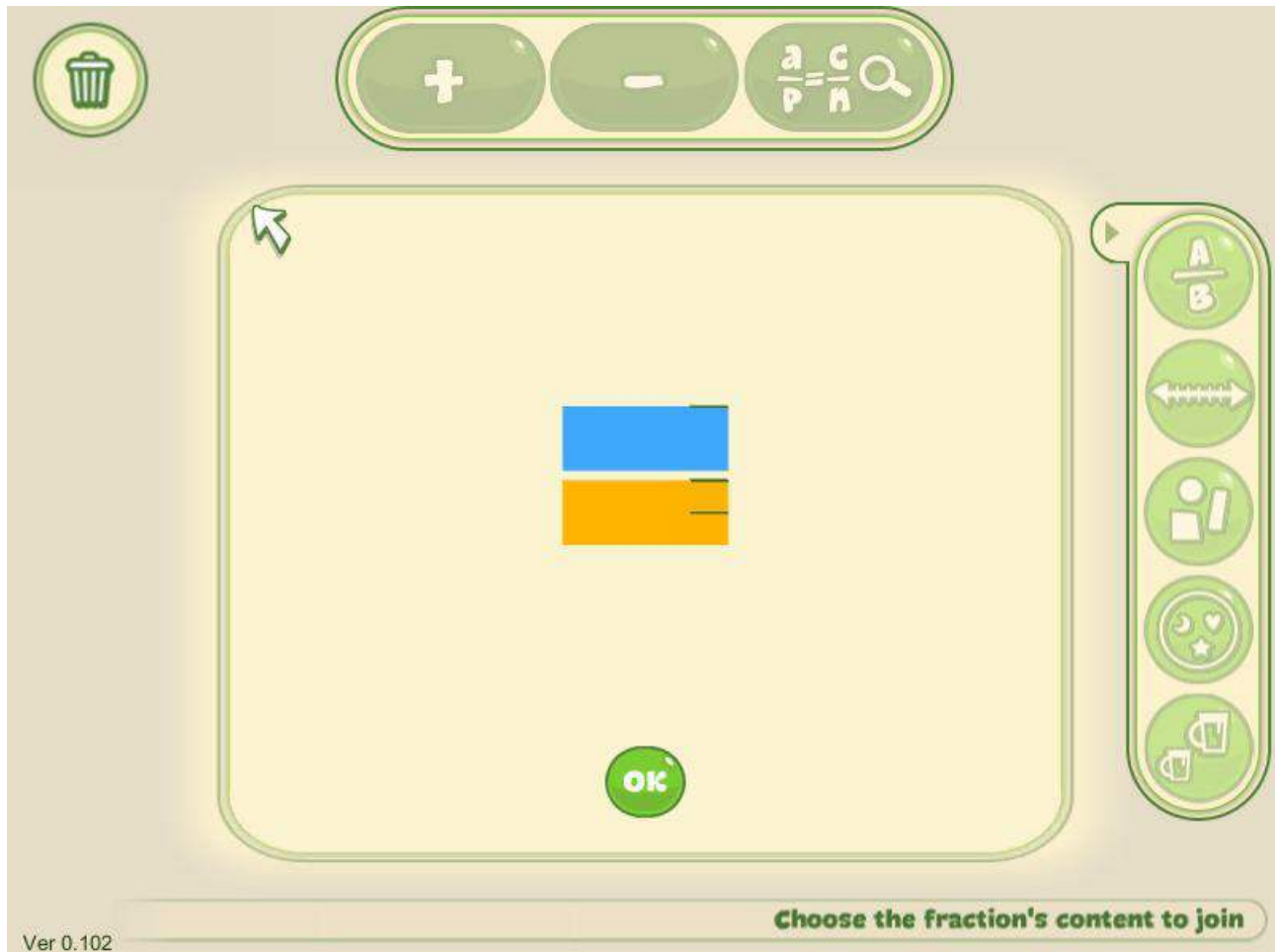
This menu consist of four entries:

- Join
- Taking away
- Compare
- Find Parent



*Figure 11 - The actions menu*

When a student selects an action, a popup showing the animated action appears, to make him/her better reflect on the meaning of the action itself.



*Figure 12 - The “join” action*



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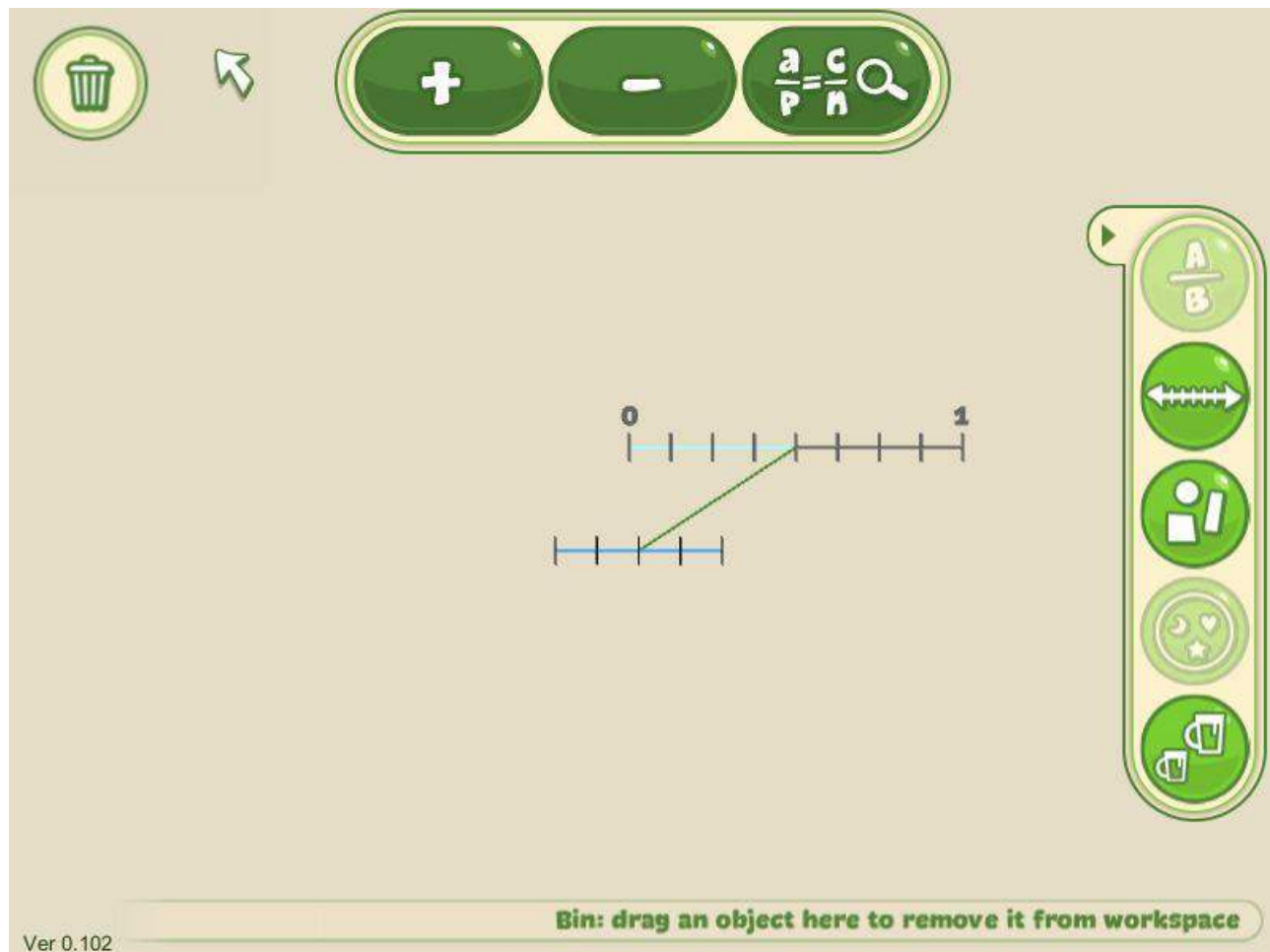


Figure 13 - The “find parent” action

#### 2.3.7 Feedback Area

At the bottom of the window, hints, tips and feedback to users are presented. Advice, instructions and suggestions are provided here to help the student in the exploration of the learning environment. Fractions Lab offers a big freedom of exploring the environment, therefore requires some feature that, while leaving the user free to explore, gives some discrete support (e.g. suggesting to him/her which tools can be used, which actions are required, or which operations are not possible). In the current state of development, there are three different types of functionalities available:

- *Integrated hint* (in green) give users a contextual help on selected functionality.

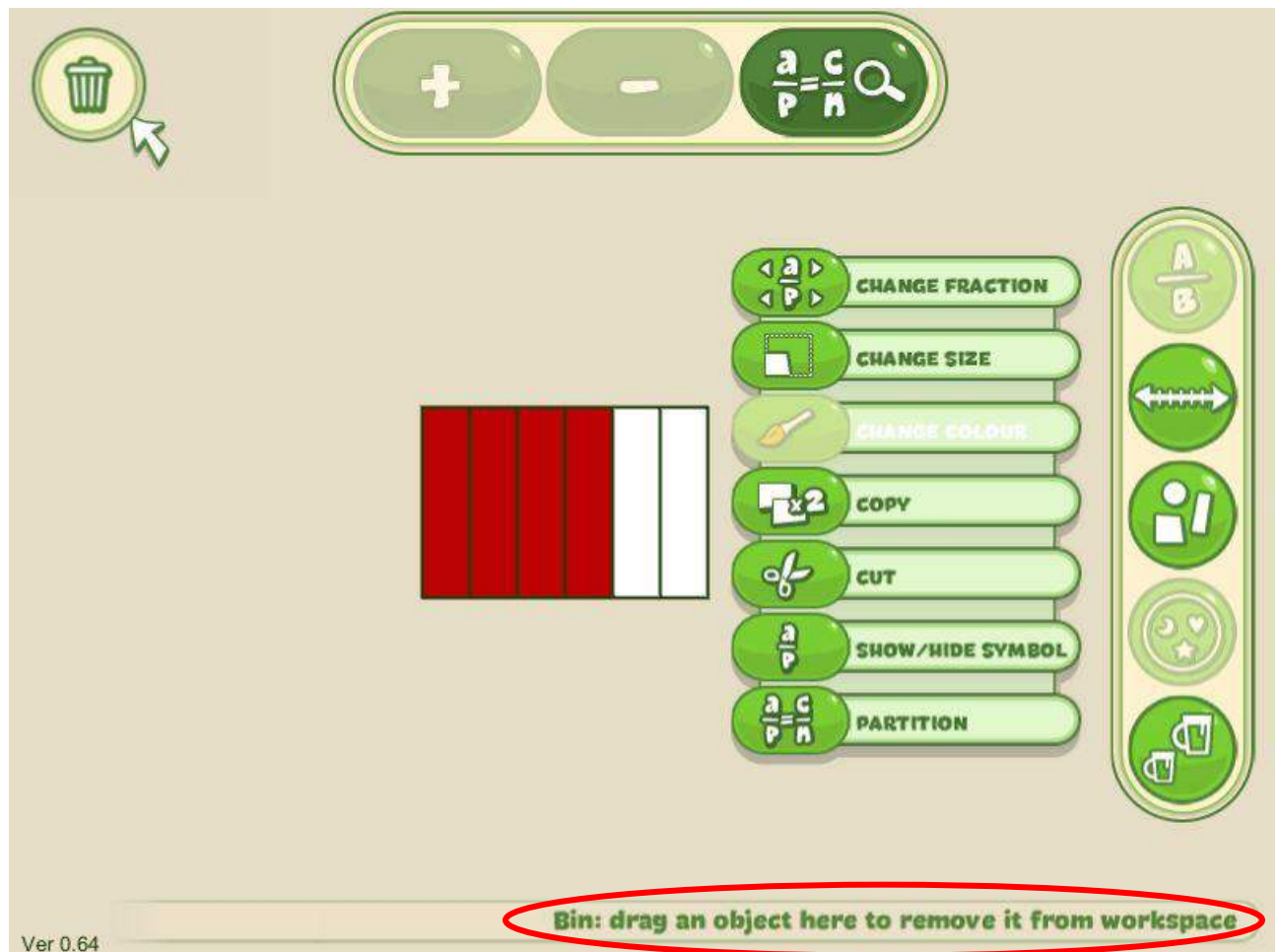


Figure 14 – Integrated hint

- *Low interruptive feedback* (in orange): coming from the iTalk2Learn platform (task dependent support), provides students with suggestions based on their learning process.



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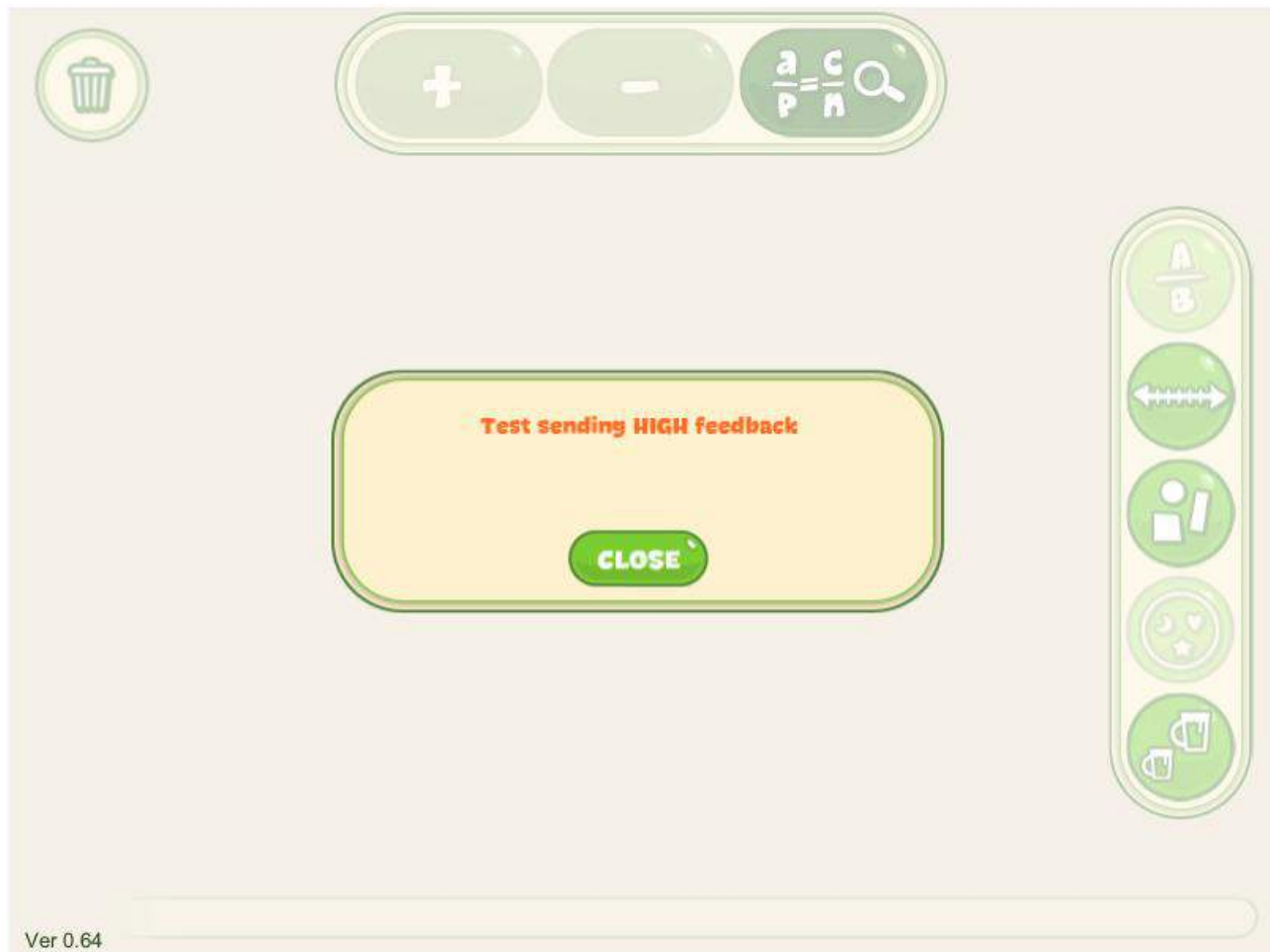


**Figure 15 – Low Interruptive feedback**

- *High interruptive feedback:* gives a feedback or message to students that requires their total attention and a voluntary action to close it. It consists of a popup opened in the middle of the screen, which prevents the student from doing any other action.



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*Figure 16 – High interruptive feedback*





## 2.4 *HCI considerations and necessary GUI harmonisation and enhancement*

Activities related to harmonisation of GUIs and usability started at M13 with T3.7. In this first phase three main topics have been addressed:

- Collection of requirements to get to a better understanding of the envisaged UIs and means of interaction with the platform.
- Technical analysis of the affordances of the underlying technologies in order to define a strategy for allowing different teams to work both on the development of the platform and on the GUIs in a separate and parallel way.
- Generation of a certain number of GUIs proposals to be analysed and selected by the consortium towards future implementation.

As a result of the above mentioned activities, we present hereby a description of the platform (at current status of development), from the point of view of user interaction. Immediately after four graphical proposals for the corresponding GUIs are introduced.

The platform consist of three type of pages that allow the user to interact with the system at different levels:

- A cover where are displayed the logo of the project, a short explanation about the platform and the login form.

The system is able to recognize whether the user is a teacher or a student. Therefore, depending on the case, some elements might be displayed or not and the subsequent page will be presented with a configuration for students or teachers

The design of the graphical proposal has focused on the following aspects:

- **the conceptual cage (Layout)**
- **the navigation**
- **the terminologies and hierarchy of the titling**



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The **conceptual cage** represents the basic layout, by which contents are sketched in specific areas. This provides the user with a reading order.

The conceptual cage is a mere, non-graphical, informational layout which summarizes the content and navigation items.

The design proposal consists of 4 horizontal bands. Starting from the top we can find:

- **Header:** containing platform logo
- **User Bar:** containing the welcome message and functions related to that specific user
- **Application:** presenting the interactive contents and the navigation (back, next)
- **Bottom area:** secondary elements, any possible hint

The **navigation** leads the user through the pages of the platform, answering all the fundamental questions that could arise during the visit:

- where am I?
- where have I been?
- where can I go?

It is worth to say that the conceptual cage, if properly structured, is a huge contributor to answering these questions alone.

A recognizable and consistent **navigation** allows the user to have a proper and immediate view of the contents of the platform.

The **terminologies and the hierarchy** of the titling has to be consistent with the linguistic style throughout the platform. Therefore if a page is named "WoZ" it should be always indicated with the same name, and all the related buttons/links should bear the same name (e.g. Back to WoZ, Go to WoZ, Welcome to WoZ etc.).

The graphical proposals are of course a consequence of the considerations described above and take inspiration from the look & feel of the iTalk2Learn logo. The 4 graphical proposals have different characteristics that can be summarized as follows:



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#### A. Clean and linear graphics. Standard and professional appeal

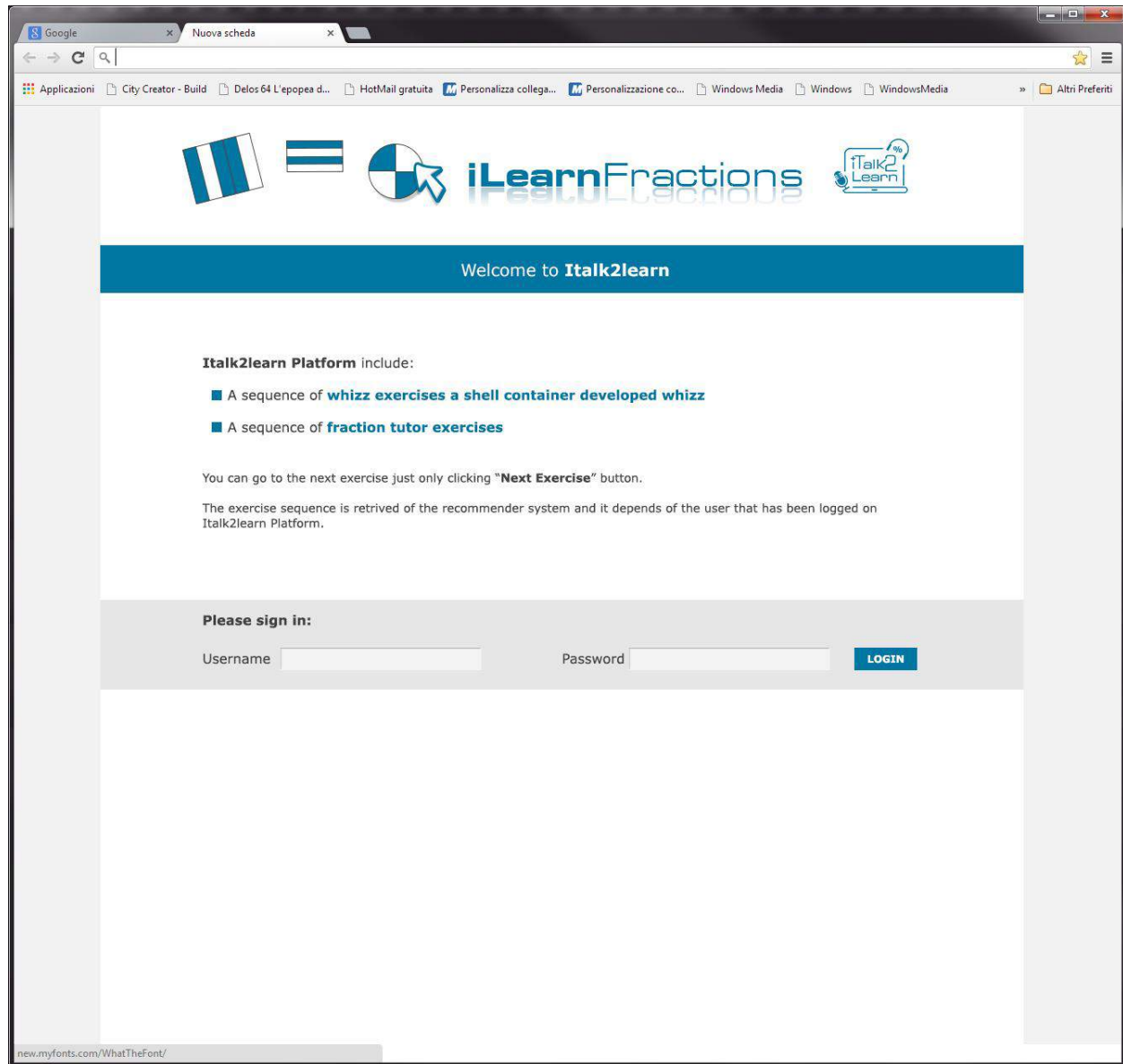
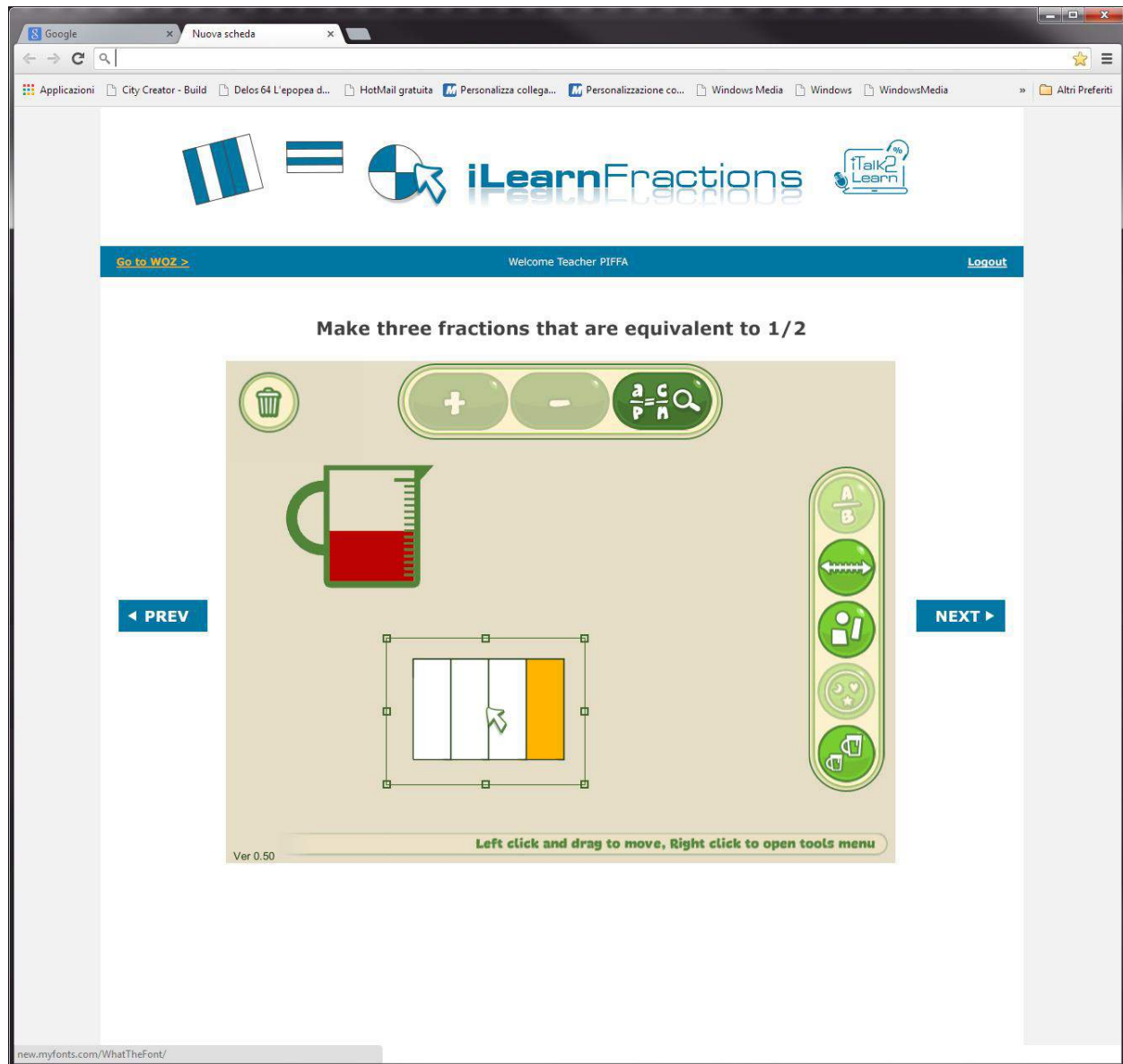


Figure 17 - OPTION A - Login Page



**Figure 18 – OPTION A - A snapshot with Fractions Lab in use**



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#### B. Panels and buttons with soft curved lines, offer a touch of color to the navigation

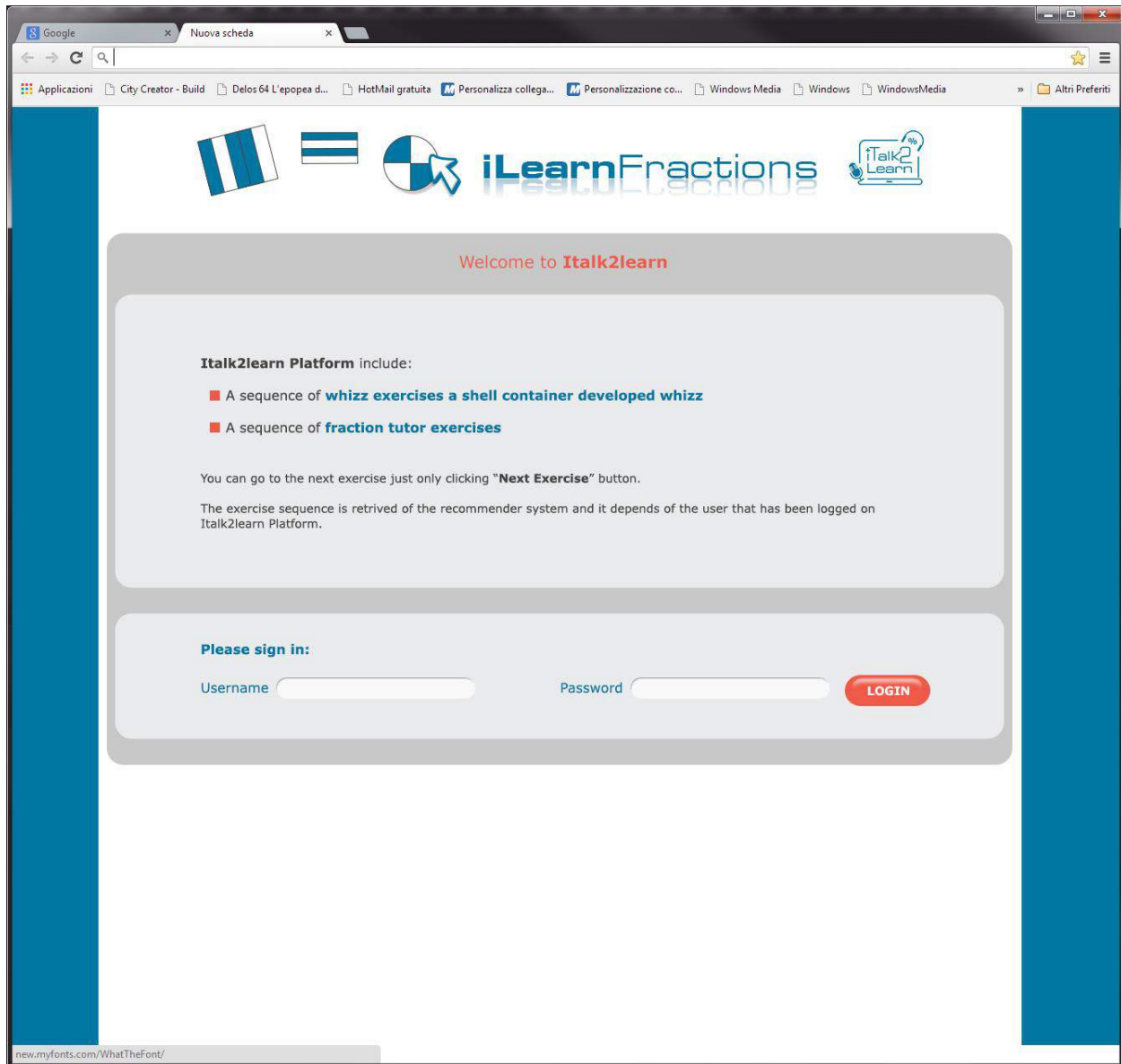
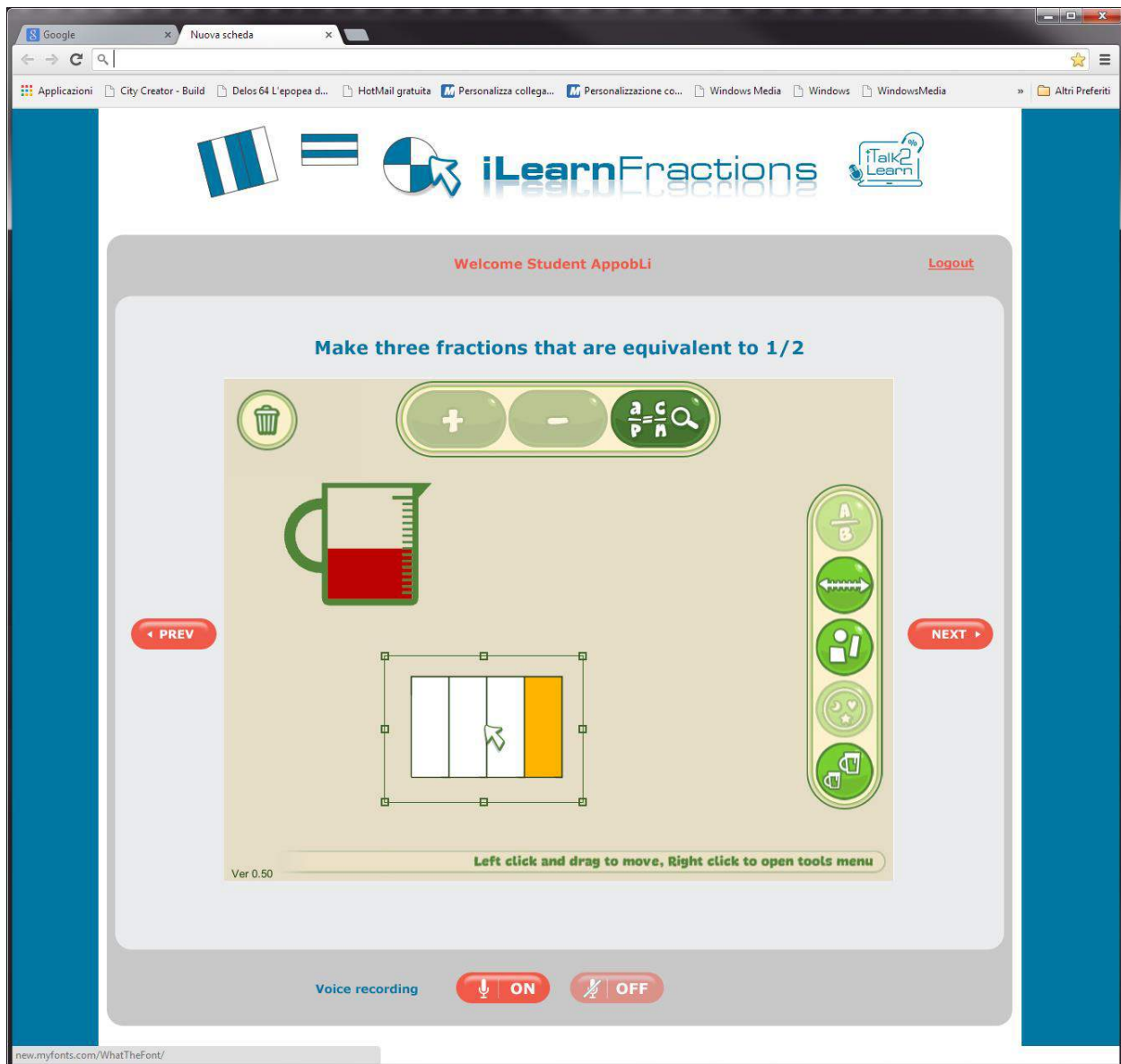


Figure 19 – OPTION B – Login Page



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**Figure 20 – OPTION B - A snapshot with Fractions Lab in use**



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- C. In this version it has been included a graphic element, the zigzag line coloured, which contribute to lighten the tone. More playful appeal.

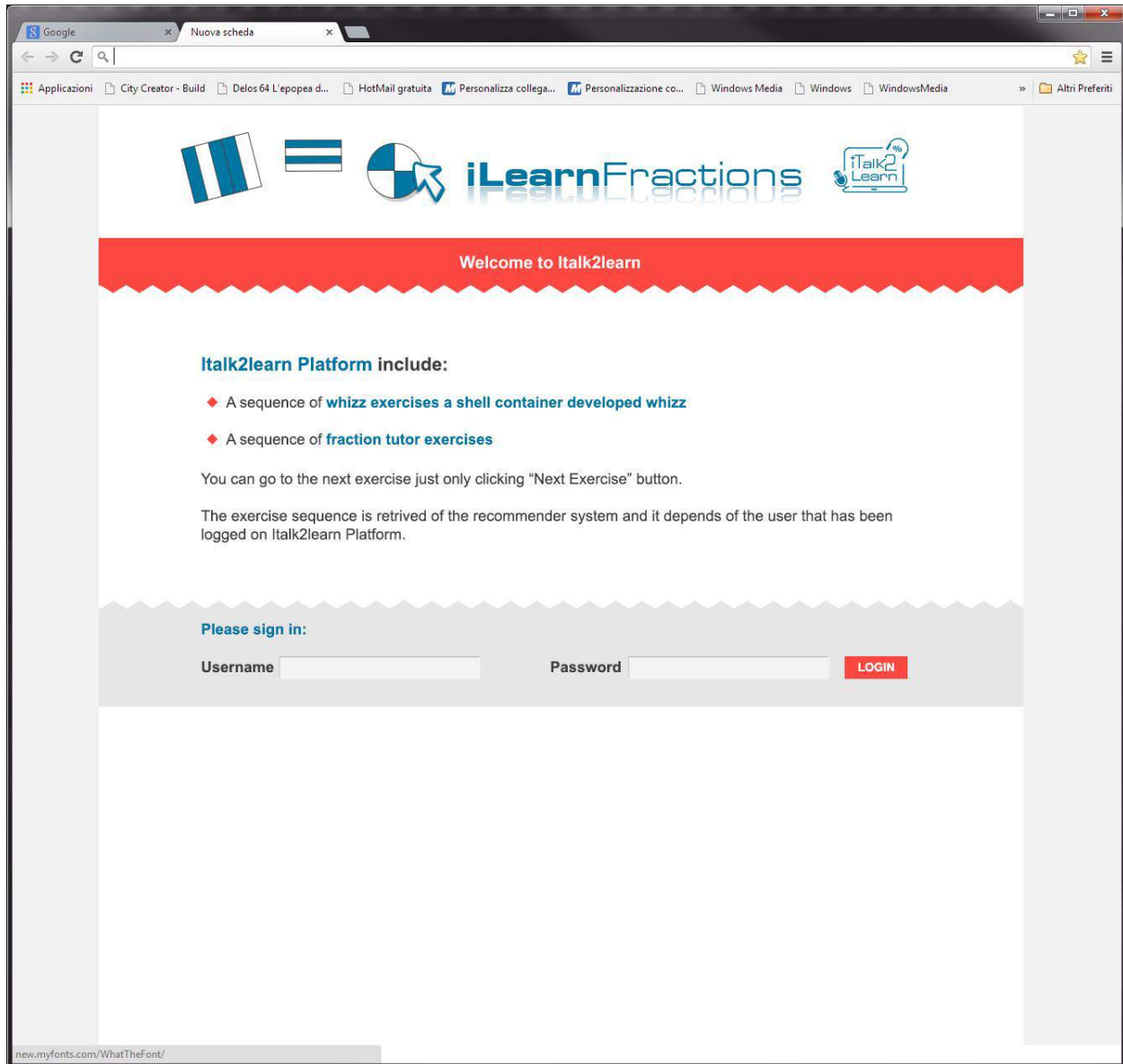
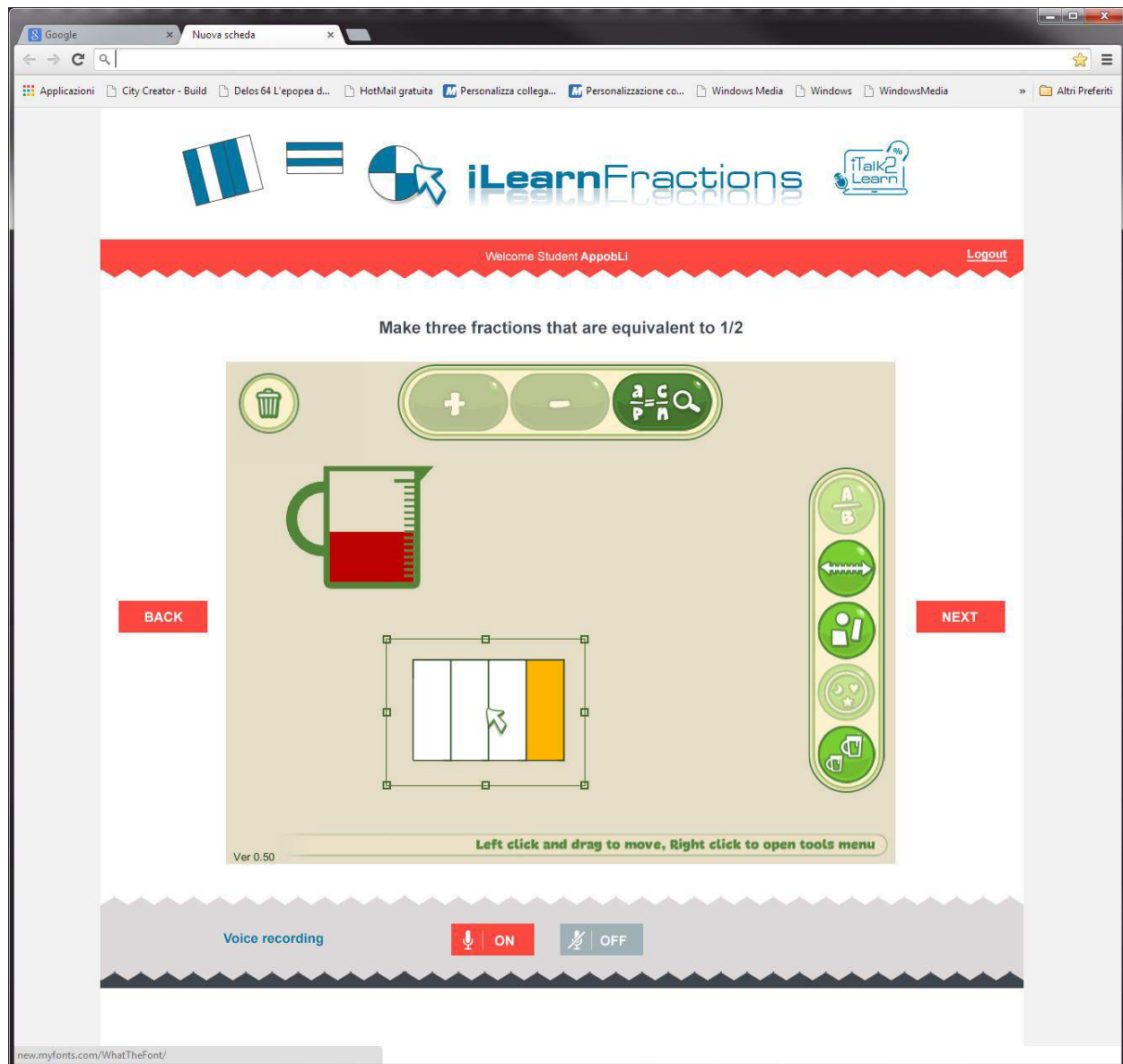


Figure 21 – OPTION C – Login Page



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**Figure 22 - OPTION C - A snapshot with Fractions Lab in use**





### D3.4.1 Initial report on methods and prototype for intuitive interaction interfaces for robust learning

D. In this version the zigzag element has the same color of the iTalk2Learn logo.

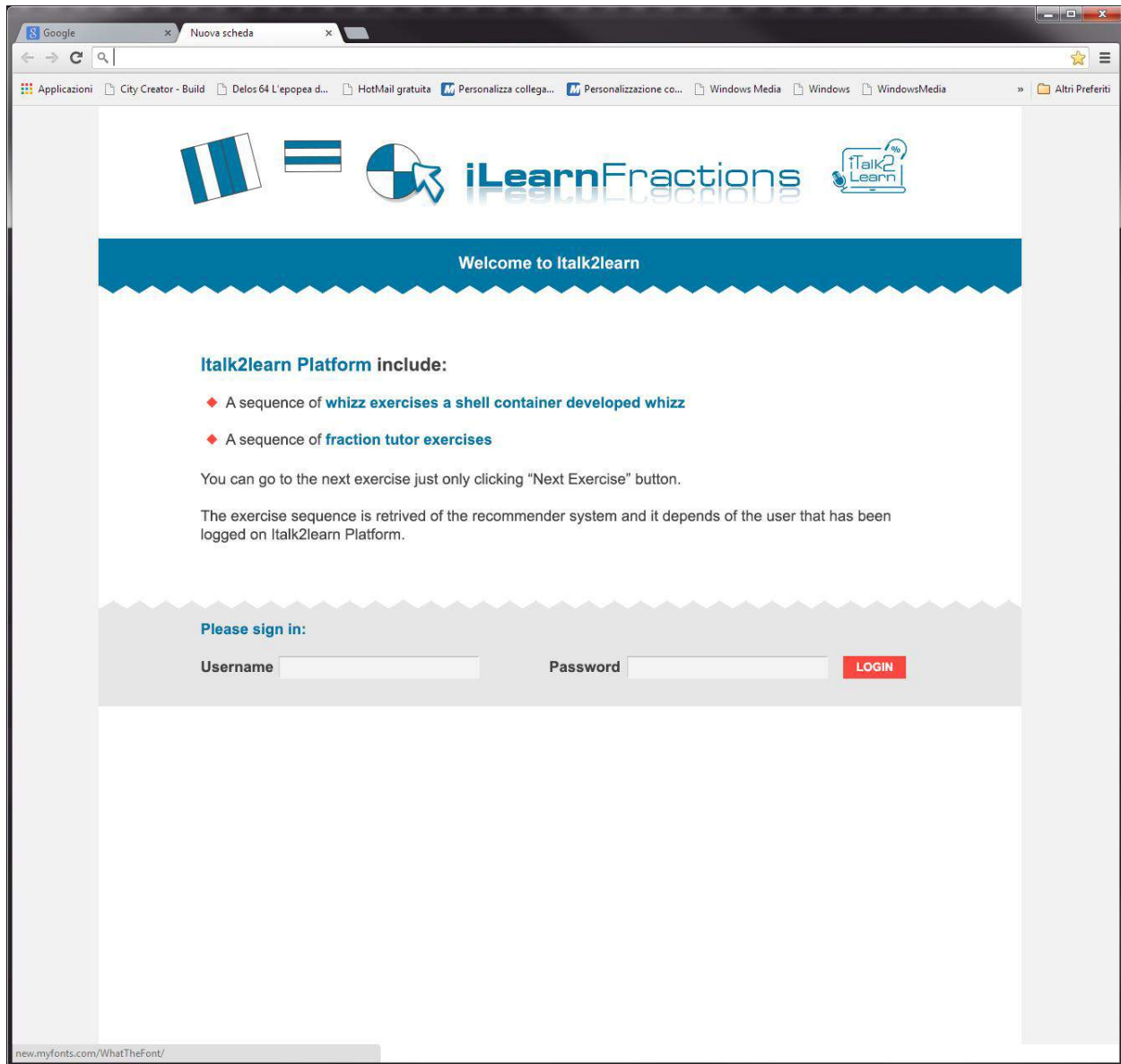
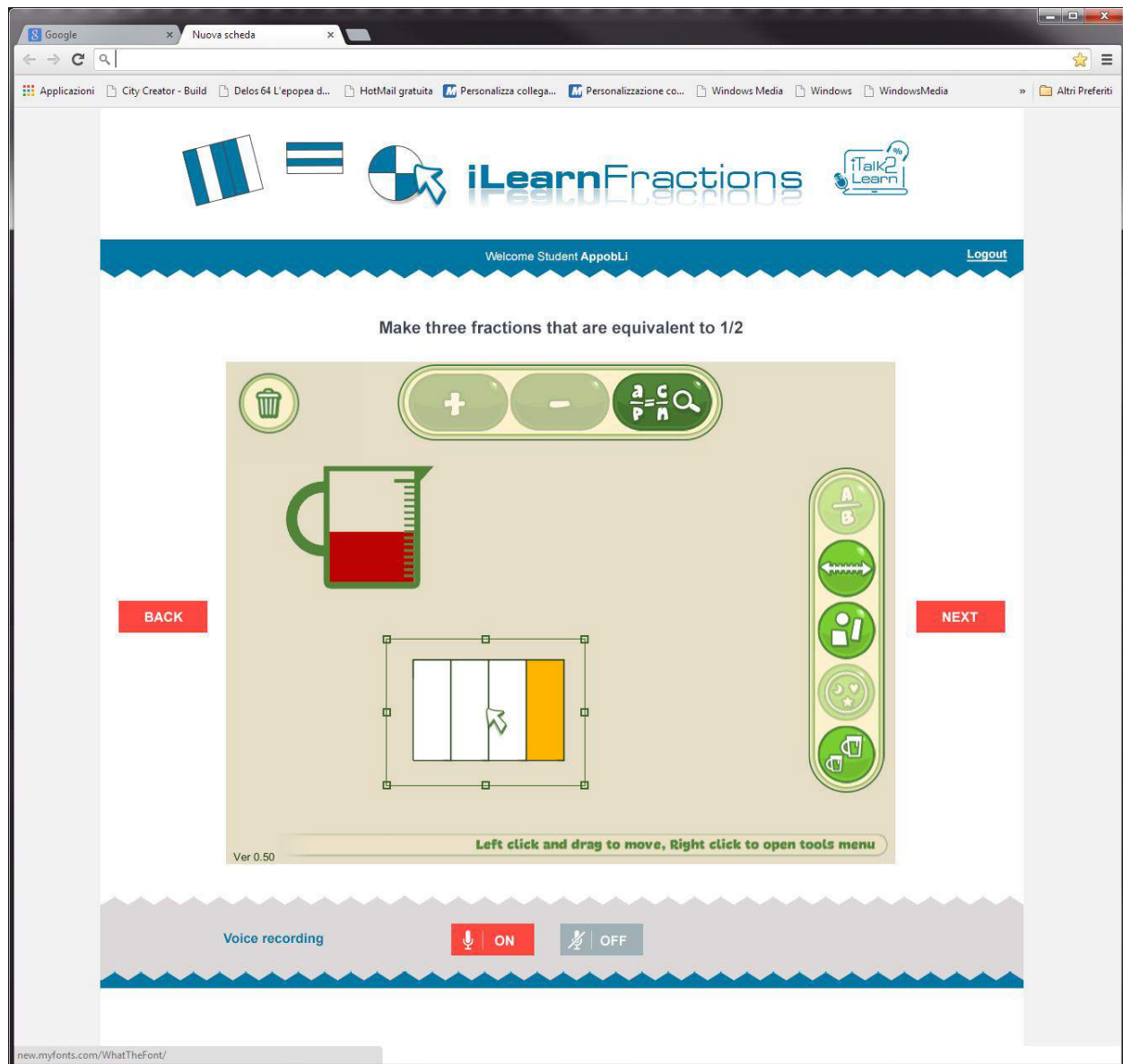


Figure 23 - OPTION D - Login Page



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**Figure 24 - OPTION D - A snapshot with Fractions Lab in use**



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## 2.5 Risks and Contingency actions for WP3

The risk analysis reported in the DoW showed no specific risks related to the tasks of WP3, but it was referred to more generic contingency (agreement among partners, departures of key figures for the project, difficulty of reaching young learners). None of this case occurred so far, nevertheless, in the course of the development of WP3, our attention has been focused on possible exposures that could undermine the activities planned for next period. The following table summarizes our analysis:

**Table 1 WP3 Risk management table**

Potential Risk	Risk Level	Impact	Contingency plan
Students do not perceive Fractions Lab in a positive way (e.g. they find it difficult to use, ...)	Low	High	Fractions Lab has been designed in accordance with the feedback collected from the students by IOE and is constantly verified during several studies in schools (see D5.1 and D5.2).  Furthermore, since Fractions Lab has been designed in a modular way, this allows to make changes in a rather simple way, redesigning the part to be replaced, without having to redesign the entire system.
Fractions Lab cannot be integrated in the platform	Low	Low	In order to avoid this risk tests have been already conducted and the results are positive.  Moreover the possibility to intervene with changes both on Fractions Lab and on the platform lowers the risk further.



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Delay in the development of Fractions Lab	Low	Medium	<p>All the stages of development have been carefully planned. Moreover the working team can rely on the background experience of TL in the field of design and development of interactive applications.</p> <p>If a delay will occur, more resources will assist the staff already working on the project to carry out the tasks. The features that delay the accomplishment of the project will be implemented secondly, if they are not the main features</p>
Delay in the implementation of the German version of Fractions Lab	High	Low	Language localization has not been finalized yet, but the system is already able to work with different languages. The German version will be implemented by M20.
Delay in integration with task dependent support	Low	Low	<p>In order to avoid this risk some tests have been already conducted and the results were positive.</p> <p>Moreover the working team can rely on the background experience of TL and BBK in this field.</p>
Voice generated by system is not perceived as appropriate by users, because of pitch, delay, or any other reason.	Low	Medium	Initial wizard-of-oz studies have not shown any concern on this respect. UI components can be used to increase the value of speech (including timers, avatars, etc.)
Google speech production engine stops being freely available	Low	High	In the unlikely case that this functionality stopped being freely available in the lifetime of the project, we have already successfully tested other freely available technologies like Festival



### **3 Conclusions and next steps**

#### ***3.1 Behavioural interaction interpretation for enhanced learner understanding***

After identifying features, classes, instances and methods like above we are ready to collect data for a concrete feature analysis and a training of the chosen emotion and affect classification methods. Hence, as a next step RUB, IOE and Whizz will conduct studies in which speech of students and their actions are recorded and students affective states as well as under-challenge, over-challenge and flow will be reported. The labelling of these data will be done by the tutor and could be added by a retrospective annotation of another reviewer. However, in the literature one can find further labelling strategies like self-labelling of the student (see e.g. D'Mello, 2008, D'Mello, 2007). To cover the different labelling strategies, UHI plans to develop additionally a small offline tutoring tool for experiments in which the students themselves label their behaviour according to the tasks. However, for little children it might be difficult to analyse themselves. Therefore, self-labelling is often applied in experiments with at least college students, as done for instance in (D'Mello, 2007). UHI will conduct the experiments with this tool with university students after creating tasks appropriate for university students.

#### ***3.2 Speech production***

The speech production subsystem is working as planned. Next steps are incrementally choosing the best voices (there is more than one available on some languages) according to user acceptance as observed in the experimental studies.

#### ***3.3 GUI framework for exploratory learning activities in elementary mathematics (ELE)***

In this deliverable we reviewed and illustrated all the functionalities of Fractions Lab. The development of the Fractions Lab followed the timeline provided in the DoW and further activities are related to integration with the platform and with task dependent support system developed by BBK.

#### ***3.4 HCI considerations and necessary GUI harmonisation and enhancement***

This task has been undertaken at Month 13, accordingly with the DoW and will finish at the end of the project.

Next steps foresee the choice of one of the four graphical proposals by the consortium and the



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consequent implementation in the platform. The harmonisation and GUIs design and development is a continuous process as the platform will evolve throughout the project's lifetime.



## 4 References

- Ackermann, E. (1991). From decontextualized to situated knowledge: Revisiting Piaget's water-level experiment. In I. H. S. Papert (Ed.), *Constructionism* (pp. 269-295). Norwood, NJ: Ablex Publishing Corporation.
- Barger, A., & Byrd, K. (2011). Motivation and computer-based instructional design. *Journal of Cross-Disciplinary Perspectives in Education*, 4(1), 1-9.
- Blackler, A. L., & Hurtienne, J. (2007). Towards a unified view of intuitive interaction : definitions, models and tools across the world. *MMI-Interaktiv*, 13, 36-54.
- Chuang, M. L. (2009). *Using intuitive interaction technology to promote learning of mathematics in young children*. presented at the meeting of the World Conference on Educational Multimedia, Hypermedia and Telecommunications, Chesapeake, VA.
- Cooper, S. M., Wilkerson, T. L., Montgomery, M., Mechell, S., Arterbury, K., & Moore, S. (2012). Developing a Theoretical Framework for Examining Student Understanding of Fractional Concepts: An Historical Accounting. *Forum on Public Policy*, 2012(1).
- D'Mello, S., Picard, R. and Graesser, A. 2007. Towards An Affect-Sensitive AutoTutor. *Intelligent Systems*, IEEE, Vol. 22, Issue 4, pp. 53 – 61.
- D'Mello, S.K., Craig, S.D., Witherspoon, A., McDaniel, B. and Graesser, A. 2008. Automatic detection of learner's affect from conversational cues. *User Model User-Adap Inter*, DOI 10.1007/s11257-007-9037-6.
- Goldenberg, E. P., Cuoco, A. A., & Mark, J. (1998). A role for geometry in general education. In R. Lehrer & D. Chazan (Eds.), *Designing Learning Environments for Developing Understanding of Geometry and Space* (pp. 3-44). Mahwah, NJ: Lawrence Erlbaum Associates.
- Haipeng, M., Krzywinski, A., Fujita, T., & Sugimoto, M. (2012). RoboTable: An Infrastructure for Intuitive Interaction with Mobile Robots in a Mixed-Reality Environment. *Advances in Human-Computer Interaction*, 2012, 1-10. doi:10.1155/2012/301608
- Hansen, A. (2008). *Children's geometric defining and a principled approach to task design*. Warwick University.
- Hoyles, C. (1985). What is the point of group discussion in mathematics? *Educational Studies in Mathematics*, 16, 205-214.
- Hu, X., Tang, L., Tang, J. and Liu, H. (2013). Exploiting Social Relations for Sentiment Analysis in Microblogging. In *Proceedings of the Sixth ACM WSDM Conference (WSDM '13)*.





### **D3.4.1 Initial report on methods and prototype for intuitive interaction interfaces for robust learning**

- Hunting, R. P., & Sharples, C. F. (1988). Fraction Knowledge in Preschool Children. *Journal for Research in Mathematics Education*, 19(2), 175-180.
- Janning, R., Schatten, C. and Schmidt-Thieme, L. 2014. Automatic Subclasses Estimation for a Better Classification with HNNP. To appear in Proceedings of the 21<sup>th</sup> International Symposium on Methodologies for Intelligent Systems (ISMIS 2014), June 2014, Roskilde, Denmark.
- Kafai, Y. B., & Harel, I. (1991). Learning through consulting: When mathematical ideas, knowledge of programming and design, and playful discourse are intertwined. In I. Harel & S. Papert (Eds.), *Constructionism*. Norwood, NJ: Ablex Publishing Corporation.
- Kafai, Y. B., & Harel, I. (1991). Learning through design and teaching: Exploring social and collaborative aspects of constructionism. In I. Harel & S. Papert (Eds.), *Constructionism*. Norwood, NJ: Ablex Publishing Corporation.
- Krohn-Grimberghe, A., Busche, A., Nanopoulos, A. and Schmidt-Thieme, L. 2011. *Active learning for technology enhanced learning*. In Proceedings of the European Conference on Technology Enhanced Learning (EC-TEL 2011), Springer, pp. 512-518.
- Luz, S. 2013. *Automatic Identification of Experts and Performance Prediction in the Multimodal Math Data Corpus through Analysis of Speech Interaction*. Second International Workshop on Multimodal Learning Analytics, Sydney Australia, December 2013.
- Mack, N. K. (1990). Learning Fractions with Understanding: Building on Informal Knowledge. *Journal for Research in Mathematics Education*, 21(1), 16-32.
- Mamede, E., Nunes, T., & Bryant, P. (2005). *The equivalence and ordering of fractions in part-whole and quotient situations*. presented at the meeting of the 29th Conference of the International Group for the Psychology of Mathematics Education, Melbourne.
- Morency, L.P., Oviatt, S., Scherer, S., Weibel, N. and Worsley, M. 2013. *ICMI 2013 grand challenge workshop on multimodal learning analytics*. In Proceedings of the 15th ACM on International conference on multimodal interaction (ICMI 2013), pp. 373-378.
- Newstead, K., & Murray, H. (1998). *Young students' constructions of fractions*. presented at the meeting of the Twenty-second International Conference for the Psychology of Mathematics Education, Stellenbosch, South Africa.
- Nunes, T. (2006). *Fractions: difficult but crucial in mathematics learning*. In T. a. L. R. Programme (Ed.).
- Pekrun, R. 2006. *The Control-Value Theory of Achievement Emotions: Assumptions, Corollaries, and Implications for Educational Research and Practice*. J. Edu. Psych. Rev., pp. 315-341.
- Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-Computer Interaction*. Harlow: Addison-Wesley.
- Qi, F., Bao, C., Liu, Y. 2004. *A novel two-step SVM classifier for voiced/unvoiced/silence classification of speech*. International Symposium on Chinese Spoken Language Processing, pp. 77-80.



### D3.4.1 Initial report on methods and prototype for intuitive interaction interfaces for robust learning

- Raskin, J. (1994). Intuitive equals familiar Communications of the ACM. 37(9), 17. Retrieved from <http://www.asktog.com/papers/raskinintuit.html>
- Sadegh, M., Ibrahim, R., Othman, Z.A. 2012. Opinion *Mining and Sentiment Analysis: A Survey*. International Journal of Computers & Technology, Vol. 2, No. 3.
- Saif, H., He, Y. and Alani, H. 2012. *Semantic Sentiment Analysis of Twitter*. In Proceedings of the 11th International Semantic Web Conference (ISWC 2012).
- Schatten, C. and Schmidt-Thieme, L. 2014. *Adaptive Content Sequencing without Domain Information*. In Proceedings of the Conference on computer supported education (CSEDU 2014).
- Schuller, B., Batliner, A., Steidl, S. and Seppi, D. 2011. *Recognising realistic emotions and affect in speech: State of the art and lessons learnt from the first challenge*. Speech Communication, Elsevier.
- Sundberg, J. (1998). Expressivity in singing. A review of some recent investigations. *Logopedics, Phoniatrics, Vocology*, 23, 121-127.
- Vygotski, L.L.S. 1978. Mind in society: *The development of higher psychological processes*. Harvard university press.
- Woolf, B., Burleson, W., Arroyo, I., Dragon, T., Cooper, D. and Picard, R. 2009. *Affect-aware tutors: recognising and responding to student affect*. Int. J. of Learning Technology, Vol. 4, No. 3/4, pp. 129-164.
- Worsley, M. and Blikstein, P. 2011. *What's an Expert? Using Learning Analytics to Identify Emergent Markers of Expertise through Automated Speech, Sentiment and Sketch Analysis*. In Proceedings of the 4th International Conference on Educational Data Mining (EDM '11), pp. 235-240.