



# ENVISAGE

## ENhance VIRTUAL learning Spaces using Applied Gaming in Education

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### D4.4 – Final version of the “Virtual labs authoring tool”

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<b>Abstract:</b> Deliverable D4.4 provides an improved version of the Authoring Tool by addressing the evaluation feedback received during Phase I Pilots, integrating the outcomes of the second development cycle, as well as introducing optimizations with respect to the quality of the generated content and the integrity of the generated labs for each platform (desktop, web).	
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## Executive Summary

In this technical report, we present the final version of the “Virtual Labs authoring tool” which is an integrated software consisting of authoring features, game analytics visualizations, and content adaptation capabilities for the creation of virtual labs. Compared to its initial version, the Authoring Tool has been significantly improved by incorporating several new features such as the ability to author a second type of labs namely the Chemistry Labs that together with the Wind Energy Labs are the two kinds of supported virtual labs. The Chemistry Lab is a first person view game (FPV) whereas the Wind Energy Lab is a real time strategy game (RTS). Significant effort was allocated into the implementation of web interfaces that allow the configuration of the Chemistry template and also the new version of Wind Energy template. Effort was also allocated in integrating the modules of game analytics and visualizations as part of the Authoring Tool dashboard, as well as in implementing an A/B strategy making mechanism that allows teachers to deploy this kind of strategies without having to compile and re-deploy new labs. Moreover, a score prediction mechanism has been also integrated as part of the Authoring Tool that can predict the score of the learners as a result of certain design choices and investigate the impact of these choices on how the learners are distributed in the 4 PISA categories of performance. This would facilitate the teachers to design virtual labs ensuring the properly balanced distribution of students across these categories.

ENVISAGE’s Authoring Tool was moved to a new server, namely a high-end server with two XEON processors<sup>1</sup> that boosted significantly the response time of web interfaces. The server was a part of the infrastructure of CERTH, as it was mentioned in the proposal in Section 4, so no costs were induced. The url of the portal of the final version is:

<http://envisagelabs.itl.gr>

Registration and Login is required.

All code repositories are publicly available in GitHub under the organization ENVISAGE-H2020. The main code repository is the ‘Virtual-Labs-Authoring-tool’. The link to these repositories is:

<https://github.com/Envisage-H2020>

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<sup>1</sup> 24 processors with 128 GB of RAM running Ubuntu 16 server edition with php 7

## Abbreviations and Acronyms

CMS	Content Management System
API	Application Program Interface
GUI	Graphic User Interface
JSON	JavaScript Object Notation
WebGL	Web Graphics Language
SDK	Software Development Toolkit
MAT	Unity3D Material file format
OBJ	Wavefront Object file format
MTL	Wavefront Material file format
LMB	Left Mouse button
RMB	Right Mouse button

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## 1. Introduction

The evaluation of the initial version of the Authoring Tool [3] not only from educators but also from the project reviewers that have been designated by the commission, led to a number of useful conclusions that were taken into consideration in the development of its final version. First, the concept of authoring 3D labs using web interfaces was very well-taken by both project reviewers and educators. This is due to the novelty of our methodology that is based on combining two very different technologies namely web content management systems and runtime game engines. However, there were several implementation issues that caused the authoring process of virtual labs to be rather challenging. Therefore, significant improvements were introduced with respect to the user-friendliness of the Tool, while new features were also introduced such as the support for authoring a new type of labs, namely Chemistry Labs, and the integration of all existing analytics, visualization and content adaptation modules.

This report is organized as follows. In Section 2, we present in detail the developments that have been undertaken in response to the comments received during the evaluation of the Tool, the new features that have been introduced and the integration activities that have been carried out. In Section 3 and 4 the authoring process of a virtual lab is described for the cases of Chemistry and Wind Energy. Finally, a summary of this work and directions towards future developments are described in Section 4.



## 2. Authoring tool

In this section, we present the evaluators’ comments and the activities that have been carried out to address them; the new features introduced with respect to the previous version of the Authoring Tool; and the different modules that have been integrated as part of the Authoring Tool dashboard.

### 2.1 Feedback on the first prototype

The evaluation procedure entails the evaluation of the authoring tool with respect mainly to its usability and user-friendliness, as well as the evaluation of the virtual labs. Only the Wind Energy Lab was fully supported in the first prototype of the authoring tool, while the chemistry lab was only demonstrated to the educators for explaining the functionalities that will be offered by this type of labs. During the Phase I evaluation pilots there were only a few comments reported for the virtual labs, while the vast majority of them concerned the usability of the Authoring Tool. In particular, since the educators involved in the trials were unfamiliar with the process of creating 3D content and virtual environments, they experienced difficulties into understanding the 3D authoring process of the authoring tool.

#### 2.1.1 Authoring tool evaluation

In general, the educators characterized the Authoring Tool very interesting, innovative and customizable and that it will definitely attract the interest of the learners as reported in Deliverable 5.2 (Oct. 2017) [4] describing the evaluation results of Phase I pilots. However, there were many comments regarding its user friendliness and usability. Similar comments were also received from another group of teachers that tested the Authoring Tool in the context of a workshop that was organized by ENVISAGE in conjunction with the Panhellenic Physics Conference in March 2018<sup>2</sup>.

##### 2.1.1.1 Consolidated comments from Phase I (usability experts & educators)

The comments regarding the authoring tool are dealt as follows.

#### Home page:

- **Comment:** The authoring tool switches between using the term “Game” and “Virtual Lab”.  
**Action:** We have kept the terminology consistent across all interfaces of the Authoring Tool so as to avoid any ambiguities.
- **Comment:** The login field is placed at the end of the page below the fold. This makes it harder to find for a first-time user and is inefficient for the returning user.  
**Response:** We have placed login in a more prominent place.
- **Comments:** The buttons (“Make your game”, forward and back) on top of the banner image do not link to anything.  
**Response:** The links were fixed in the new version of the Authoring Tool.
- **Comment:** The commenting and searching functionalities seems rather irrelevant to the core purpose of the Authoring Tool.  
**Response:** Both functionalities were removed.
- **Comment:** The banner image depicts the interface of the virtual lab including the

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<sup>2</sup> Workshop 8 at <http://eef17.gr/workshops/>

buttons. This is confusing to a first-time user. Consider cropping the image or use an image that places the virtual lab in a context for instance on a screen with a student in front.

**Response:** The image was cropped out so as to become more representative for the actual use of the Tool.

## **Project Manager page:**

### **Consistency in terminology**

- **Comment:** The functionality of “Projects” could be unclear to new users as the list will most likely be empty. Making the title more active and changing “Projects” into “Existing projects” or similar could help explain the functionality of the list better.

**Response:** The title was changed to become more informative.

- **Comment:** The functionality of “New game project” could be unclear to new users. Making the title more active and changing “New game project” into “Create new project” or similar could help explain the functionality of the list better. This would also provide more consistency with the “Create” button for the function.

**Response:** The title of the functionality has been changed accordingly.

### **Match between system and the real world**

- **Comment:** Active word use: “Game project type” could be confusing for users, as the authoring tool is for creating virtual labs and subsequently because it does not inform the user of what action is required to continue. Making the title more active by changing “Game project type” into “Choose project type” or similar could help explain the action required by the user more.

**Response:** The title has been changed.

### **Help and documentation**

- **Comment:** Documentation is needed: The two project types are not explained further and no additional information about them is offered to the user. Explain the project types to the user by either having a “more details button”, link to an additional page explaining the types or similar.

**Response:** We have added a button for explaining each project type.

### **Aesthetic and minimalist design**

- **Comment:** The dark bar below the wordpress topbar consists of a header that links to the login page and an unused menu bar with a search function. These elements are in their current state of little use to a user and take of space moving the actual content further down the page. Remove the dark bar or minimize it and incorporate navigation that embraces the relevant pages in the authoring tool.

**Response:** The dark bar was removed.

- **Comment:** Unnecessary limitations: The title of the project can have a minimum of five characters for naming the project. While this might have an underlying reasoning behind it, it does not make sense from a user experience point of view, as it limits the user. Remove the limitations on characters to allow the user more freedom when choosing the name of a project or scene (This goes for the whole authoring tool).

**Response:** The limitation was made less strict by lowering down the limit to at least two characters.

## **Project Editor**

### **Help and documentation**

- **Comment:** The project editor presents an overview of the scenes that will eventually compose the virtual lab but there is no explanation neither visual or textual of how the different elements are connected in the compiled virtual lab. Leaving the user with questions like: When are the credits shown? In the case where the user creates multiple scenes in which order will these appear in? Adding explanatory texts and previews even if they are only simplistic would greatly help guide the user.

**Response:** We have added a help button that provides a simplistic overview of the correspondence between authoring tool scenes and the lab.

- **Comment:** System terminology: Unity terms like “Asset”, “Scenes” and “Compile” may well be unfamiliar to the user. Add explanatory text to or consider using more self-explanatory terms.

**Response:** We have added help material in order to educate the teachers about what is a scene and what is an asset. Replacing the terms with specific words could reduce the ability of the tool to cover many different use cases.

### **Match between system and the real world**

- **Comment:** The structure of the workflow when creating a lab: The first elements the user can interact with on the page are the “Compile Game” button, the “Add new 3D asset” and the “Add new scene” links. However, when looking at the ideal workflow for the users, this might not be the ideal first interactions to start with e.g. compiling is most like the last. When the user first enters the project editor there are three predefined scenes already set up. On a smaller screen these are displayed below the fold as these represent the minimal lab project a user can create. Maybe the default scenes should be moved further up on the page to match the minimal workflow. Think about the ideal workflow for the user and let the design facilitate this. Structuring the elements in an order that match the ideal workflow for using the authoring tool would also improve the usability.
- **Response:** It is difficult to re-arrange the scenes as it requires knowledge of the form of each use case lab. Having the scenes un-arranged it is easy to cover all use cases. We are considering having pre-built scenes, so that compile button can effectively compile the lab without the need to do any modifications in the ordering of the scenes.

### **Consistency and standards**

- **Comment:** Navigation: With the dark header bar at top of the page pushing the page content down the breadcrumb trail is placed further down than conventions dictate making it harder to find. If the dark header bar is kept in place then move the breadcrumb further up.

**Response:** It has been fixed accordingly.

### **Visibility of system status**

- **Comment:** It is possible to access the Add New 3D Asset functionality from the Project Editor via “Add new 3D asset” however once a user has gone through all the steps required and created an asset the user is returned to the Project Editor page without any feedback on where the asset is placed. Either remove the feature for adding assets on the page (it is already possible to add asset from the 3D scenes) or show a library of the

created assets on the Project Editor page alike to the All Scenes functionality.

**Response:** We have adapted the second option. A library of assets is shown in the Project Editor, showing all available assets in the form of tiles with screenshots of the 3D model of the asset.

### **3D Scene page**

#### **Help and documentation**

- **Comment:** Inadequate help: Though there are some tooltips on the interface in the 3D scene, they do not adequately explain the functionality to the user e.g. the toggle button with an image of 2 arrows has the tooltip “Toggle double sided object”. There are also elements with no explanations such as the frames per seconds counter in the bottom left of the 3D view and the blue cylinder object that is fixed to the bottom of the view. Provide help and documentation that explains the features while avoiding technical language and in line with Nielsen’s heuristics uses phrases and concepts familiar to the user.

**Response:** Some of the buttons were removed from the second version. The double-sided object toggle button is removed by properly configuring the normals of the 3D models. The blue cylinder was replaced by a 2D button for the trash-bin. Explanation for the buttons were added when hovering the mouse above them.

#### **User control and freedom**

- **Comment:** The user cannot undo and redo actions made in the 3D scene. Add redo and undo functionality.  
**Response:** It is complex to add undo-redo button in the 3D environment. However, we consider it as an essential feature for future developments.
- **Comment:** On a smaller screen it is not possible to see the entire 3D scene at once and since scroll is used to navigate the 3D space it is extra difficult for users to grasp the scene in its entirety. Implement the 3D view as a responsive element that adjust to different screen sizes.  
**Response:** We have added a “Full Screen” button that resizes the 3D environment to fill the whole page.
- **Comment:** A user can add a new asset using the “Add new 3D asset” button on the 3D scene page however once a user has gone through all the steps required and created an asset the user is sent to the Project Editor page and not returned to the scene where the user originally started this may confuse the user. Return the user to the 3D scene where they started or only keep the add asset button on the project editor page.  
**Response:** It is fixed, now the user returns to the 3D editor.

#### **Error prevention**

- **Comment:** There is a save feature in the 3D scene however there is nothing reminding the user to use it before navigating to other parts of the website. So, a user may easily lose their work if they navigate away without saving. Add a warning popup or similar reminding the user to save before navigating elsewhere.
- **Response:** A warning popup was added.

## Credits

### Help and documentation

- **Comment:** Missing preview: The credits page only consists of a textbox and a submit button and the user is therefore not aware of where, how, when and it what format the credits will be shown. A preview of the credits would help document for the user how the credits will look.  
**Response:** We have added a help button that shows how the Credits scene looks in the game.
- **Comment:** Description needed: The text describing the textbox says “Edit Credits text” and is therefore not offering the user any suggestions for what type of information the labs credits could contain. “Edit Credits text” could e.g. be removed and a text containing a more thorough description could be added below the header “Credits”.  
**Response:** Fixed.

### Match between system and the real world

- **Comment:** Inconsistency in terminology: The breadcrumb trail for credits references the credit pages as a “2D editor” and while this might be a 2D scene editor, the terminology is more focused on a system thinking than the user-friendly terminology. Changes the name to Credits.
- **Response:** Fixed.

## Main Menu:

### Match between system and the real world

- **Comment:** Inconsistency in terminology: Main menu featured image can be an ambiguous term. Changes the name to e.g. “Choose main menu background” to emphasis what the image will be used for.  
**Response:** Changed.
- **Comment:** Inconsistency in terminology: The breadcrumb trail for credits references the credit pages as a “2D editor” and while this might be a 2D scene editor, the terminology is more focused on a system thinking than the user-friendly terminology. Changes the name to Main menu.  
**Response:** Fixed.

### Help and documentation

- **Comment:** Missing preview: Although there is a preview of the picture (if you upload one), it is unsure what enabling the sections: “options”, Login and “help” will look like. (The Help pages suffer the same faith). Have a preview where the user in real time can see the changes or a sketch explaining (not real time) where the different features and images will be placed.  
**Response:** A preview appears by pressing the help button.
- **Comment:** Missing preview: The Help pages suffer from the same faith as above and it is also not clear if the help page is a page on its own or a part of the main menu. Have a preview where the user in real time can see the changes or a sketch explaining (not real time) where the different features and images will be placed.  
**Response:** Fixed as in the previous comment.
- **Comment:** Missing description: “Enable Sections” are not self-explanatory, especially not

Options, which could be a variety of things. Maybe a preview of the main menu pages (as explained above) would solve this issue and otherwise a tooltip, more information link/fold out or explanatory text could also help to improve this.

**Response:** Fixed as in the previous comment.

### **3D Asset Creator:**

#### **Error prevention**

- **Comment:** It is easy to overlook the “Select a category” drop down and if a user first uploads an asset and then later chooses a category then the uploaded disappears. Recommendation: The Information and Object properties element should first appear once the user has chosen the relevant asset category.

**Response:** Fixed according to recommendation.

#### **Help and documentation**

- **Comment:** Unclear description: It is unclear as a user where and by whom the text in the description box will be visible. In the scene for the users or in the 3D scenes? And why is it necessary? Maybe prolong the default text in the box explaining to the users where the text will be visible.

**Response:** Most of the Assets are pre-built in the new version. So the asset creation is mainly targeting for the administrator of the system that has to use the interface for making and sharing assets to the educators. We assume that the administrator knows the role of description input.

- **Comment:** Developers language: Maybe all users will not be aware of what FBX, MTL and OBJ files are and when you use one or the other. The same goes for textures. Offer the user explanations for the different types of files and when they are often used.

**Response:** Fixed as in the previous comment.

### **Consumer:**

#### **Match between system and the real world**

- **Comment:** Double meaning: The word consumer can have a different meaning depending on the context it is used in and the user might be confused or misled by the term. Supply the user with a bit of explanatory text when choosing the category. Some tooltips directly on the different parameter of energy could also guide the user's choice when setting them (e.g. mark by using a question mark).

**Response:** Some remarks were added below the selection widget.

### **Decoration:**

#### **Help and documentation**

- **Comment:** Missing description: the asset has no description. While the functionalities of a decoration asset could be more obvious to the users than e.g. consumer and producer, a text explaining this category's purpose would reassure or inform users further.

**Response:** An explanatory text was added.

### **Producer:**

#### **Help and documentation**

- **Comment:** Missing documentation: When testing this asset, we became aware that this

asset could be conceived as not being a 3D asset but settings for the wind range during the game. Explain to the user what the X and Y axis means, to ensure they make informed decisions when setting them.

**Response:** X and Y axis for turbine performance graph are automatically inferred from the max energy field, and therefore, they were removed.

- **Comment:** Missing documentation: The same issue as above is applicable for the producer options. Maybe tooltips or other explanations of the different settings to ensure they make informed decisions when setting them. Some decision made for one parameter might also affect the power productions charges or other producer options and the user needs to be made aware of this.

**Response:** Explanation texts were added.

## **Terrain:**

### **Help and documentation**

- **Comment:** Missing description: there are settings Physics, Construction Penalties and Income. A text explaining this category’s purpose would reassure or inform users further.
- Response:** Explanatory text was added nearby the fields.

### 2.1.1.2 Comments received in the Panhellenic Physics Conference Workshop

Apart from the evaluation of the first prototype of the authoring tool that was reported in September 2017, there was an evaluation in the Panhellenic conference workshop in Thessaloniki in March 2018 by 15 teachers<sup>3</sup>. This workshop was considered a great opportunity to collect additional feedback about the authoring tool from educators that were completely external to the project. Their feedback was collected through questionnaires that were delivered to them to fill-in voluntarily after the end of the corresponding session. In this section, we have collected the responses of the teachers regarding the authoring tool that were below the average score (4 out of 7) indicating the problems of the system. Comments with at least 3 opinions below the score of 4 are taken into consideration. It is important to note that we have decided to adopt this rather unfavorable limit on which questions to select so as to obtain a qualitative overview of all “negative” comments that were made during the workshop. In this way, we take into consideration the “negative” opinion of users even if they constitute a minority among the respondents. Overall, most of the comments were related to the user friendliness of the system. That is the time needed to find the necessary information, to interact with the system, to interpret error messages, and to recover from mistakes. Analytically:

- 1) **Question:** Using the system in my job will enable me to accomplish tasks more quickly (Scores given: 4, 3, 3, 4, 3, 4, 4, 2).  
**Response:** We have implemented mechanisms that allow building virtual labs rapidly such as built-in assets that are available to all labs of the same type. The 3D editor user interface was enhanced through new graphic and input interfaces. The response of the server is much faster in the revised tool since the system migrated from a server with i5-2nd generation CPU into a XEON 22 CPU server. The server software was also upgraded from php 5 into php 7.
- 2) **Question:** Using the system would improve my job performance (Scores: 4, 4, 3, 4, 4).  
**Response:** 5 out of 15 educators thought that the system will have mild improvement in the effectiveness and quality of their teaching. This reflects that a percentage of educators is more familiarized with more traditional teaching methodologies without involving 3D gaming technologies. This might also be due to the high amount of time required by the first version of the system for making a virtual lab, which we have improved, in the final version.
- 3) **Question:** I would find the system useful for my job (Scores: 4, 3, 4)  
**Response:** The system was not complete in the initial prototype of the authoring tool so that it could persuade all educators about its usefulness. However, the remaining 12 educators rated the system with a high score.
- 4) **Question:** Using the system would enhance my effectiveness on the job: (Scores: 4, 3, 4, 4, 4).  
**Response:** 5 out of 15 educators respond that their effectiveness in teaching would have mild improvement with the virtual labs authoring tool. Although it is an opinion of the minority, we need to focus our future questionnaires on the unsatisfied educators because they did not state the reason for this mild improvement. In addition, the Authoring Tool could greatly benefit from becoming integrated with an LMS (Learning Management System) that can relate the authoring of virtual labs with learning material

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<sup>3</sup> Workshop 8 in <http://eef17.gr/workshops/>



for the learners. This is out of the scope of ENVISAGE as LMS for WordPress are already available in the market by several companies (LearnPress<sup>4</sup>, LearnDash<sup>5</sup>, LifterLMS<sup>6</sup>). Also, although not a full LMS built on WordPress, the Edwiser Bridge<sup>7</sup> plugin enables the integration of the popular (and free/open source) LMS Moodle with a WordPress instance. It lets import and sync courses, users, and categories, and also control student enrollment in a Moodle course from within WordPress. In the future we will seek collaboration with an LMS provider either commercial or open source.

- 5) **Question:** Learning to operate the system would be easy for me (Scores: 4, 3, 2, 3, 2, 3, 4).

**Response:** We have improved the help material in order to allow the educators to more easily learn how to operate the system. The instructive web pages are complemented by tutorial videos that can be more easily understood. A guided tour walkthrough will be made also available so that the authoring process is explained in-situ for beginner authors.

- 6) **Question:** I would find it easy to get the system to do what I want to do (Scores: 3, 4, 1, 4, 2, 3, 4, 2, 4).

**Response:** A reference guide was made in order help users find information about how each action can be made.

- 7) **Question:** My interaction with the system would be clear and understandable (Scores: 4, 4, 4, 2, 3, 3, 3, 4, 4, 3).

**Response:** In the final prototype we have dedicated our efforts in user-friendliness in order to improve the interaction with the system. A great variety of resources (Assets and 3D models) is already embedded a priori in the system so that the educators do not have to make their own Assets and 3D models. Also, we are working into having virtual labs a priori set up, so that the educators can do modifications on the initial labs without having to re-built the labs from scratch. The feature of making labs from scratch is also kept for the advanced users of the Authoring Tool.

- 8) **Question:** I would find the system to be flexible to interact with (Scores: 4, 4, 1, 3, 4, 3, 4, 3).

**Response:** This is related to the user friendliness that is discussed in Comments 1, 2, 4, and 5.

- 9) **Question:** It would be easy for me to become skillful using the system (Scores: 1, 3, 3, 4, 4).

**Response:** We have significantly improved the interface of the system allowing the educator to complete the authoring process with less time and effort. The interaction with the system is much faster. Web pages are loaded much faster because the site migrated to a new server. The lab has embedded 3D models, assets, and scenes. New tutorial material has been made (videos, reference guide, and help material per web page).

- 10) **Question:** I would find the system easy to use (Scores: 4, 4, 2, 1, 4, 3, 4, 3, 3, 4, 3)

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<sup>4</sup> <https://wordpress.org/plugins/learnpress/>

<sup>5</sup> <https://www.learndash.com/>

<sup>6</sup> <http://www.wpbeginner.com/refer/lifterlms/>

<sup>7</sup> <https://wordpress.org/plugins/edwiser-bridge/>

**Response:** This is related to user friendliness already discussed in Comments 1, 2, 4, and 5.

11) **Question:** I can effectively complete my work using the system (Scores: 3, 3)

**Response:** This is related to user friendliness already discussed in Comments 1, 2, 4, and 5.

12) **Question:** Overall, I am satisfied with how easy it is to use this system (Scores: 4, 3, 3)

13) **Question:** It was simple to use this system (Scores: 4, 3, 3, 3)

14) **Question:** I am able to complete my work using the system (Scores: 4, 1, 3, 4, 3)

15) **Question:** It was easy to learn to use this system (Scores: 2, 4, 4)

**Response:** All the above comments are related to user friendliness already discussed in Comments 1, 2, 4, and 5.

16) **Question:** The system gives error messages that clearly tell me how to fix problems (Scores: 1, 1, 1)

**Response:** An error showing mechanism allows alerting the user of the error occurred along with an error code to track in the reference guide.

17) **Question:** Whenever I make a mistake with the system, I recover easily and quickly (Scores: 4, 2, 4, 4, 3)

**Response:** It is not easy to implement recover mechanisms in web pages. However, it is in our plans to make an undo mechanism in the 3D editor.

18) **Question:** It is easy to find the information I needed (Scores: 3, 4, 4, 4)

**Response:** 4 out of 15 educators had mild problems in finding the information needed. We believe that with the new prebuilt scenes, assets, and 3D models, as well as the tutorial material the necessary information will be easily found by the educators.

19) **Question:** The information provided for the system is easy to understand (Scores: 3, 4, 4)

**Response:** The past user guide based on the step-by-step explanation of usage scenarios was very long and it was difficult for the users to read it. The video tutorial and the guided tour walkthroughs will help educators to understand the system easily.

In the final version of the Authoring Tool effort was mostly spent in the improvement of the web interface allowing easy interaction with the system. This was a major issue occurred by the following reason. The developers had an experience with how to operate the Unity3D environment that was transferred to the handling interfaces of the Authoring Tool given the hypothesis that educators will understand the relevance of given information which actually was not so easily understood. This was also due to the fact that educators are not IT experts, and many of them are not familiarized with 3D and VR technologies. The authoring tool was therefore enhanced by incorporating a number of built-in automations for helping the default user while preserving its advanced functionalities for the advanced users. The tool was also enriched with tutorials and help material addressed to educators assuming no experience with gaming at all.

### 2.1.2 Evaluation regarding virtual labs

In general, the comments for the Chemistry and Wind Energy virtual labs were positive indicating that the labs are rather successful in fulfilling their education purpose. The rating was in a range of scores from 1 to 5. Only the comments with score below 3 were gathered. The number of participants was 15. At least three people should rate below 3 in order for

the comment to be valuable. These comments are provided below:

- 1) **Comments:** I believe it will be hard for me (the teacher) to evaluate the student’s performance in the virtual lab: 3, 2, 3

**Response:** This comment has been dealt already with the development of the analytics tools that allow the teachers to see the students’ responses in the labs. It seems that some teachers are not familiarized with the meaning of game analytics and it is difficult for them to use it. This is coped with the increased user friendliness in the second prototype.

- 2) **Comments:** Generally, the microscopes should be used as “gates” of constructing molecules from Atoms because no microscope can be used for such a process.

**Response:** We have replaced the microscopes with laptops that were generally accepted from the educators.

Comments from the project reviewers reported in the first review meeting were also considered. Danger labels were placed inside the chemistry labs, and the alcohol box was removed in order not to miss-conceive that methanol is a drinking liquid.

## 2.2 New features and improvements

The new version of the authoring tool has many new features that are detailed below:

**Assets sharing:** There are two virtual labs projects auto generated in the installation of the plugin visible only to the administrator, one for Wind Energy (named as Energy-joker lab project) and one for Chemistry (named as Chemistry-Joker lab project), where every asset of these projects is shared to every newly generated Wind Energy and Chemistry lab projects, respectively. This allows the administrator to make assets available to all labs projects and thus have predefined assets per new lab project. This procedure allows one to drop the time required for making labs by 70%. In the previous version of the authoring tool we provided to the educators a zip folder with 3D models to make their own lab assets. However, this procedure takes a lot of time since the educators have to provide the details of an asset and upload its 3D model. The provision of 3D models also might trigger intellectual property violations as many of the 3D models have limited licenses. The new method alleviates this problem since the assets with the 3D models are predefined, allowing only the administrator to further extent the inventory of 3D assets by adding more assets to the Joker projects.

**3D models sharing:** An educator may want to make a new asset but he or she may not have any specific 3D model for that asset. For this reason, we provide all the 3D models of the shared assets in a scrollbar where the educator can select among already available 3D models in the system.

**Distinction between web server and compiling server:** Having the system split in two servers, namely the master server for the web portal, and the slave server for the compiling process, allowed the significant improvement of response times and thus the user-friendliness of the system. Also, it is possible to have more than one slave servers when the system will have many lab projects compiling requests.

**Improvements on the 3D editor (trash bin, mouse interface):** The previous version of the 3D editor had bugs and interface problems regarding the deleting process with the 3D trash

bin and the mouse interface controls for orbiting, selecting, and panning. The new deleting process has a 2D button for deletions that is easier to handle. The mouse interface was designed in order to match other software where user friendliness is studied, e.g. Unity3D.

**Analytics embodiment in the template:** The Wind Energy and Chemistry templates have by default game analytics mechanisms implemented. However, these mechanisms should be initialized uniquely for each lab. We have implemented an API with Goedle server in order to obtain unique keys for each newly generated lab project so that game analytics are not mixed between labs.

**Strategy mechanism implementation:** The labs should be modifiable without re-deployment. Therefore, we have embedded in the lab templates an http based mechanism that allows to receive a strategy, a kind of directive, on which elements to show and which to hide. This allows us to implement A/B testing efficiently.

**Textures png transparency support:** The new version supports the png format with transparency for the textures that allows the creation of trees and foliage in general efficiently.

**Chemistry lab compiling:** The chemistry lab can now be compiled.

**Support of any molecule uploading in PDB format:** Literally, any molecule 3D structure can be fed into the system independently of its complexity. The core of the authoring tool transforms the PDB format into Unity3D format allowing the 3D construction puzzle scene to work.

**User rights:** The users can only manage their own lab projects but can use also access the shared assets from the built-in lab projects.

**Help button:** Each page in the authoring tool contains a help button on the right-side part that shows information relevant only to the current page. An example is shown in Figure 2.1.

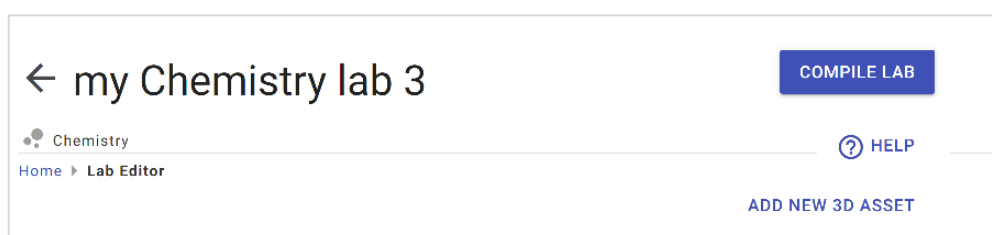


Figure 2.1: Help button shows help information for the current page of the authoring tool.

## 2.3 Authoring process improvements

The steps of the authoring process have been reduced due to the introduction of shareable assets. More specifically, the platform has pre-added lab assets available for all labs, different for each lab type (Wind Energy vs Chemistry), that allows the educators to skip the add new assets process and start directly with scenes editing. This simplified process is described in the following. The full process with adding assets is described for each lab type

in Section 3 for Chemistry and in Section 4 for Wind Energy lab.

### Step A: Create new lab

In the lab project manager as shown in Figure 2.2 type your “lab project” name, and select the type of lab. For example, type “my Chemistry Lab 2” and select the project type “Chemistry”. Then, the second interface will appear which is the project editor as shown in Figure 2.3. The upper tiles with blue background represent the scenes of the lab whereas the lower tiles with pink background represent the available assets in the lab. The available scenes and the available assets depend on the type of the generated lab. Standard are the scenes of Main Menu and Credits for all lab types.

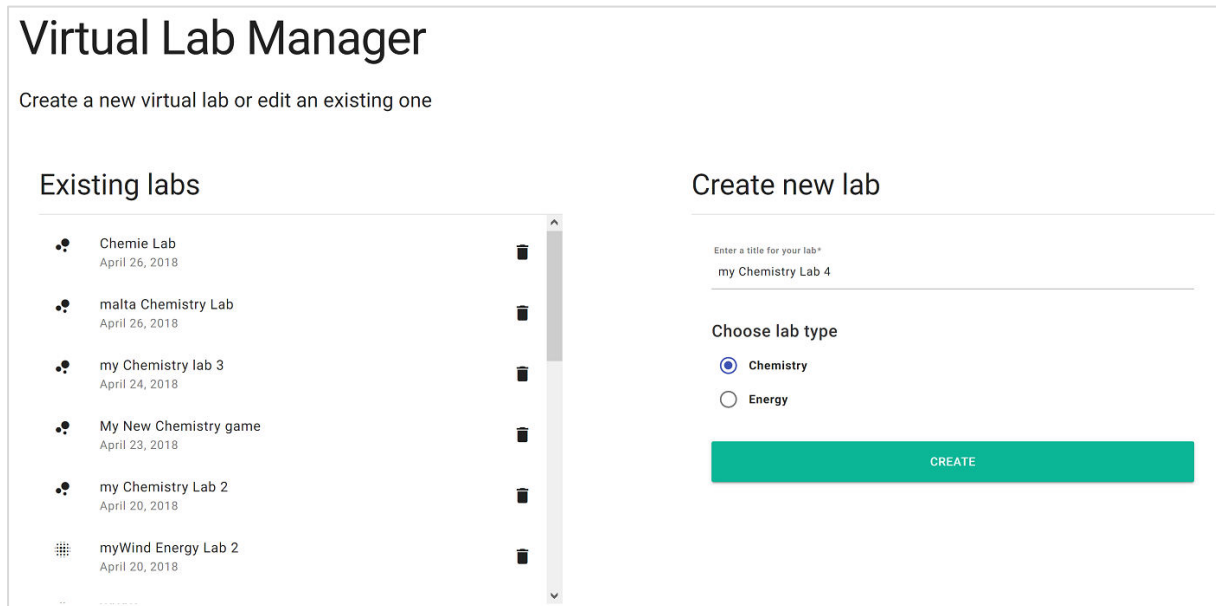


Figure 2.2: Lab project manager is the first interface. It allows to create a new lab project.

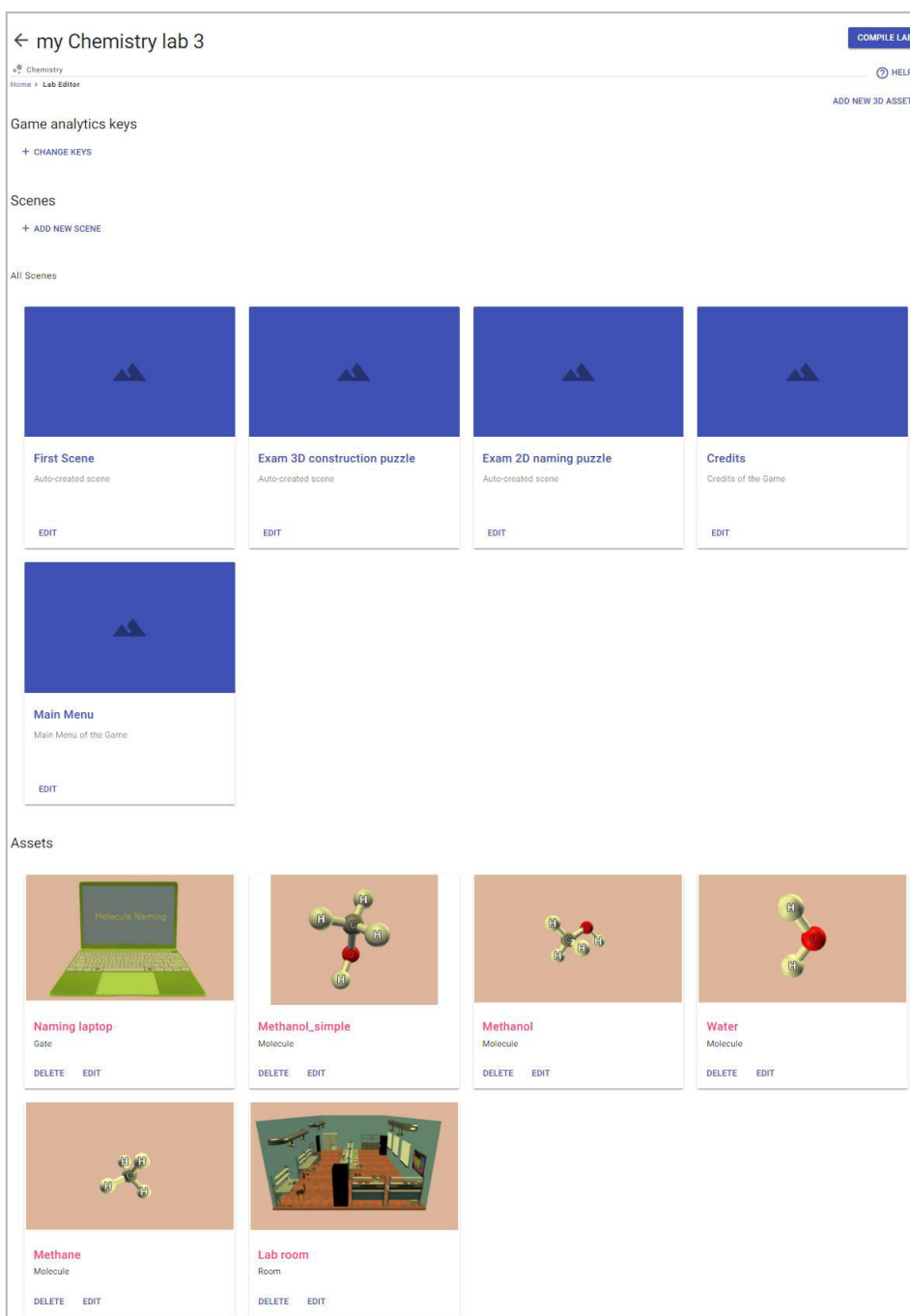


Figure 2.3: The project editor is the central page where scenes and assets can be viewed.

In the lower part of Figure 2.3, the already available assets can be seen, e.g. the lab room, the laptop, and some molecules. These assets are available for every Chemistry lab, and they cannot be edited or deleted by any user apart from the administrator. All the necessary information such as the “Game analytics keys” are pre-generated for every lab. They are shown only for solving any errors that can occur.

### Step B: Go to first scene and edit it

By selecting the “First scene”, the educator can change its name, its description, its tile image, the 3D content, and some of the properties of the 3D content. The title, the description and the tile image can change with the interface shown in Figure 2.4. The image tile can be set with two ways, either by uploading an image from your computer or by taking

a screenshot from the 3D editor.

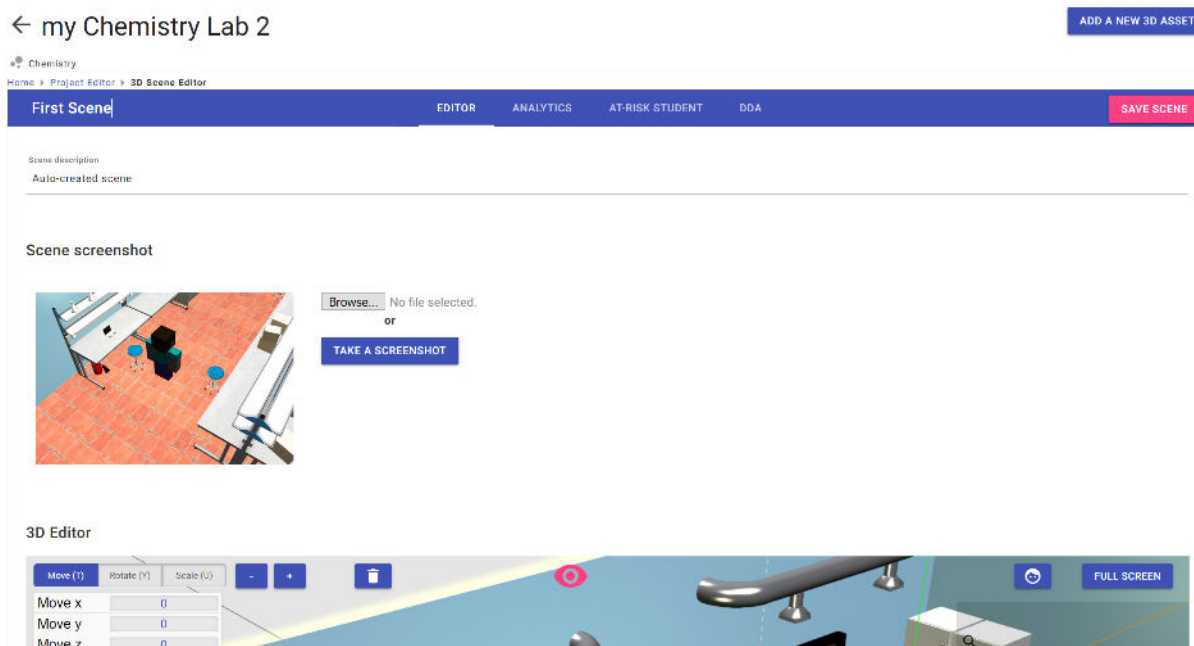


Figure 2.4: Changing the title, description, and the tile image of the scene.

The 3D content of the scene can change with the 3D editor as shown in Figure 2.5. The toolbar on the right shows the available assets that can be dragged-n-dropped in the scene. For example, in this scene we have a lab room and a laptop setup. The objects can be selected with the left mouse click (LMB). The properties of each object are shown in the left upper toolbar. It allows the modification of the position, the rotation, and the scale of the object. The button with the trash icon deletes the asset. The button with the eye makes invisible some buttons of the interface in order to allow more working space for the user. The button with the face allows viewing the scene from the avatar position. The “Full Screen” or “Exit Full Screen” button allows one to enter the full screen mode or exit it, respectively.



Figure 2.5: Editing a scene with the 3D editor.



The properties of the objects can be edited with right mouse click (RMB). For example, the properties of the laptop are shown in Figure 2.6. The laptop serves as a “Gate” between the lab scene and an exam scene. The option shows is which exam scene to load when the user approaches the laptop during the simulation.

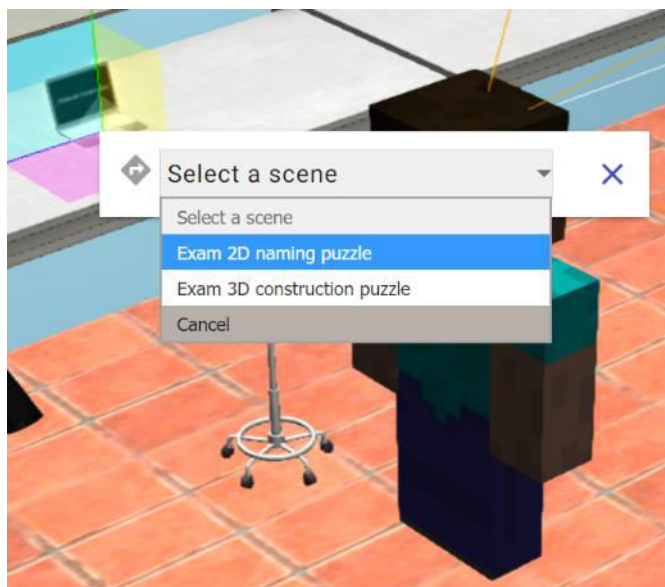


Figure 2.6: Changing the properties of the laptop object.

### Step C: Add new scenes (optional)

New scenes can be added in the project editor with the “Add new scene” button as shown in Figure 2.7. The title, the description, and the properties of the scene should be inserted. Each type of scene per lab is described in Sections 3, and 4. Each lab can be compiled with the standard scenes, so the adding of new scenes is optional.

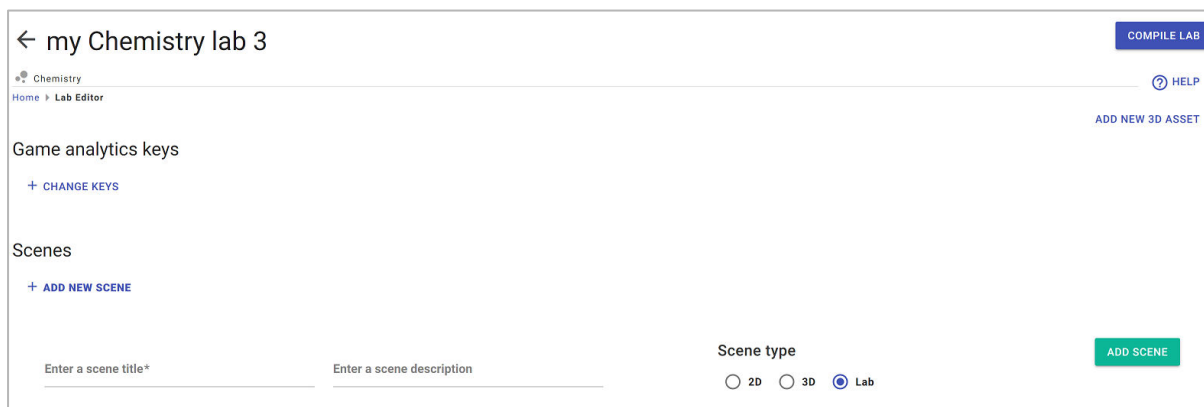


Figure 2.7: Adding new scenes in the lab.

### Step D: Edit auxiliary scenes (Main Menu and Credits)

The Main menu and the credits scene of the lab can be edited with the interfaces shown in Figure 2.8a and Figure 2.8b, respectively. The configurations allowed for the Main Menu scene are:

- a) Change the background image
- b) Toggle the appearance of "Options", "Login", "Help" buttons,



c) Change the background of the Help Scene

d) Change the text of the Help Scene.

It should be noted that the Help Scene is edited from the same interface as the Main Menu.

As regards the credits scene, the background image and the text for the credits can change.

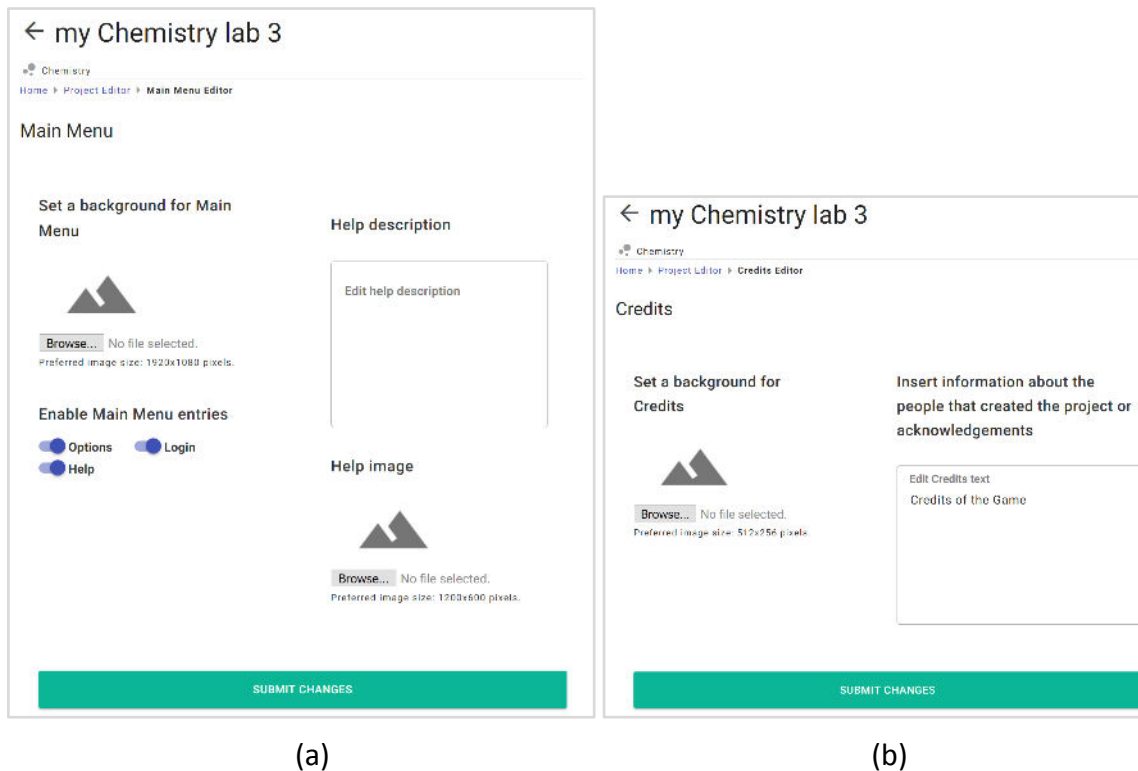


Figure 2.8: The interfaces for modifying Main Menu (a), and credits scenes (b).

### Step E: Compile lab

The lab can be compiled in the Project Editor using the “Compile Lab” button as shown in Figure 2.9. You can select the platform your lab will be compiled for. When the compiling process finishes a link to download the binary of the lab or a link to play the lab directly (if it is compiled for Web) are shown.

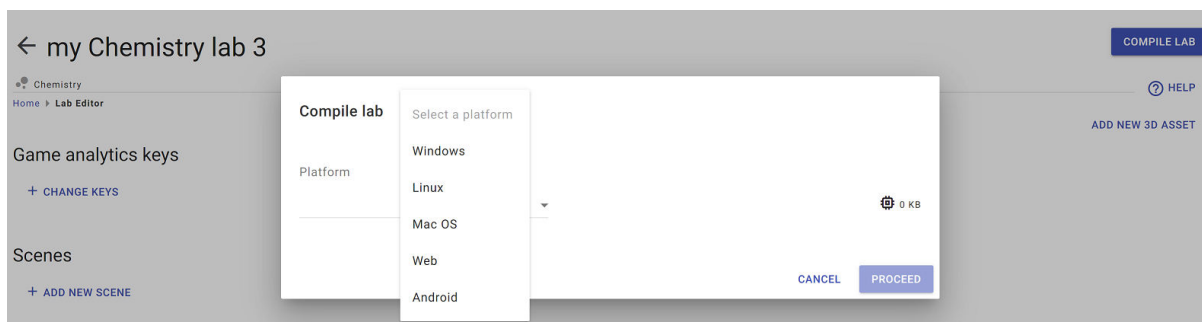


Figure 2.9: Compiling the lab.

## 2.4 Analytics dashboard

Various forms of game analytics are integrated in the platform in the form of iframe modules. All analytics modules are located inside the 3D scene editor. More specifically:

### Deep Analytics (PISA Categories)

The PISA Categories chart is rendered as an iframe below the 3D editor, as illustrated in Figure 2.10.

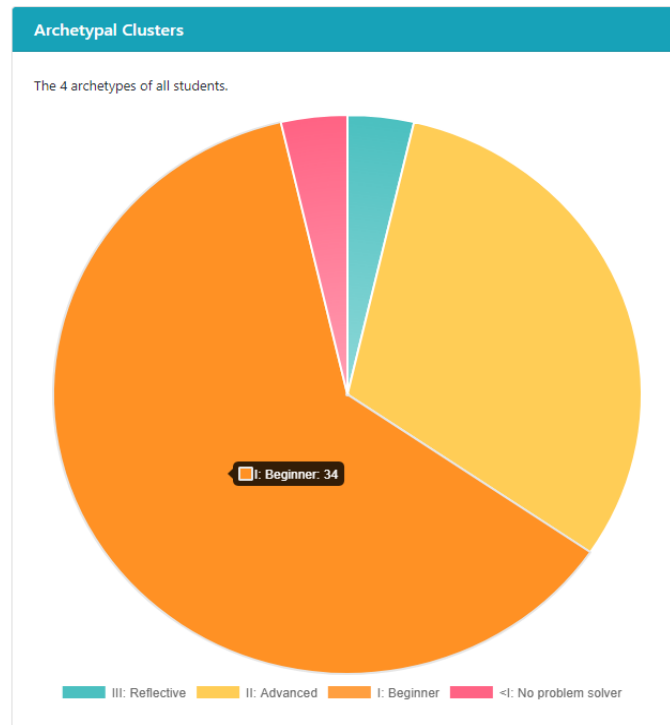


Figure 2.10: PISA Categories

This chart represents the distribution of learners in the 4 main PISA categories such as No problem solver, Beginner, Reflective, and Advanced. For an educative game, the distribution of learners in the categories should be roughly 45% in Beginners, 45% in Reflective, and 10% in Advanced.

## Shallow Analytics

The shallow analytics chart is shown when clicking on the ‘ANALYTICS’ tab that is located in the scene editor toolbar (Figure 2.11).

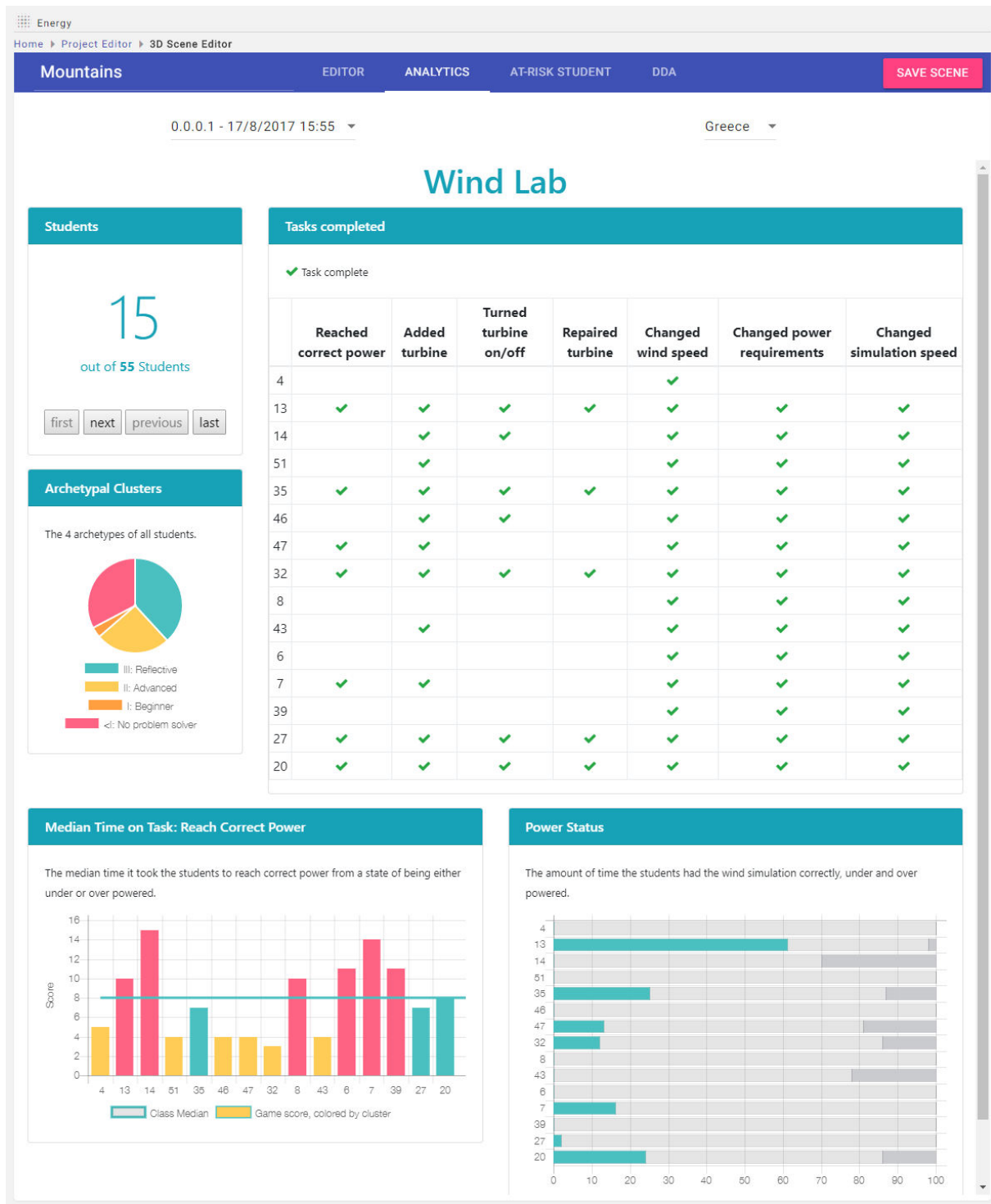


Figure 2.11: Shallow Analytics integration.

More details about the meaning of the charts can be found in the deliverables of WP2 [1] and WP3 [2].

### API integration for key generation.

For the *Student at Risk* and *Content Adaptation* analytics modules, there were some extra steps that had to be taken, in order to communicate successfully with the Goedle.io API.

First, in the user registration form of the plugin, a new field has been added that is auto-generated and serves as a secondary password as seen in Figure 2.12. This password is used in a background call to Goedle.io API that registers the new plugin user to the API.

Figure 2.12: Updated registration page.

Then after the user logs in to WordPress, and creates a new lab, another call is made to the Goedle.io API that associated the new lab with the current user id and creates an app key.

When inside the project editor, there are two fields under a new section called ‘*Game analytics keys*’, the GIO APP KEY field and the Experiment ID field. The app key that was generated through the Goedle.io API is already saved in the first field whereas the second field is empty, and is entered by the user, after an e-mail from Goedle.io is received (Figure 2.13).

Figure 2.13: Lab analytics keys section.

## Student at Risk

The next tab button in the scene editor toolbar titled ‘*AT-RISK STUDENT*’ loads the Student at Risk iframe as illustrated in Figure 2.14. The Goedle.io API call used to get the iframe contents needs only the experiment id of the project. More information about the details of this functionality can be found in the respective deliverables of WP2 [1] and WP3 [2].

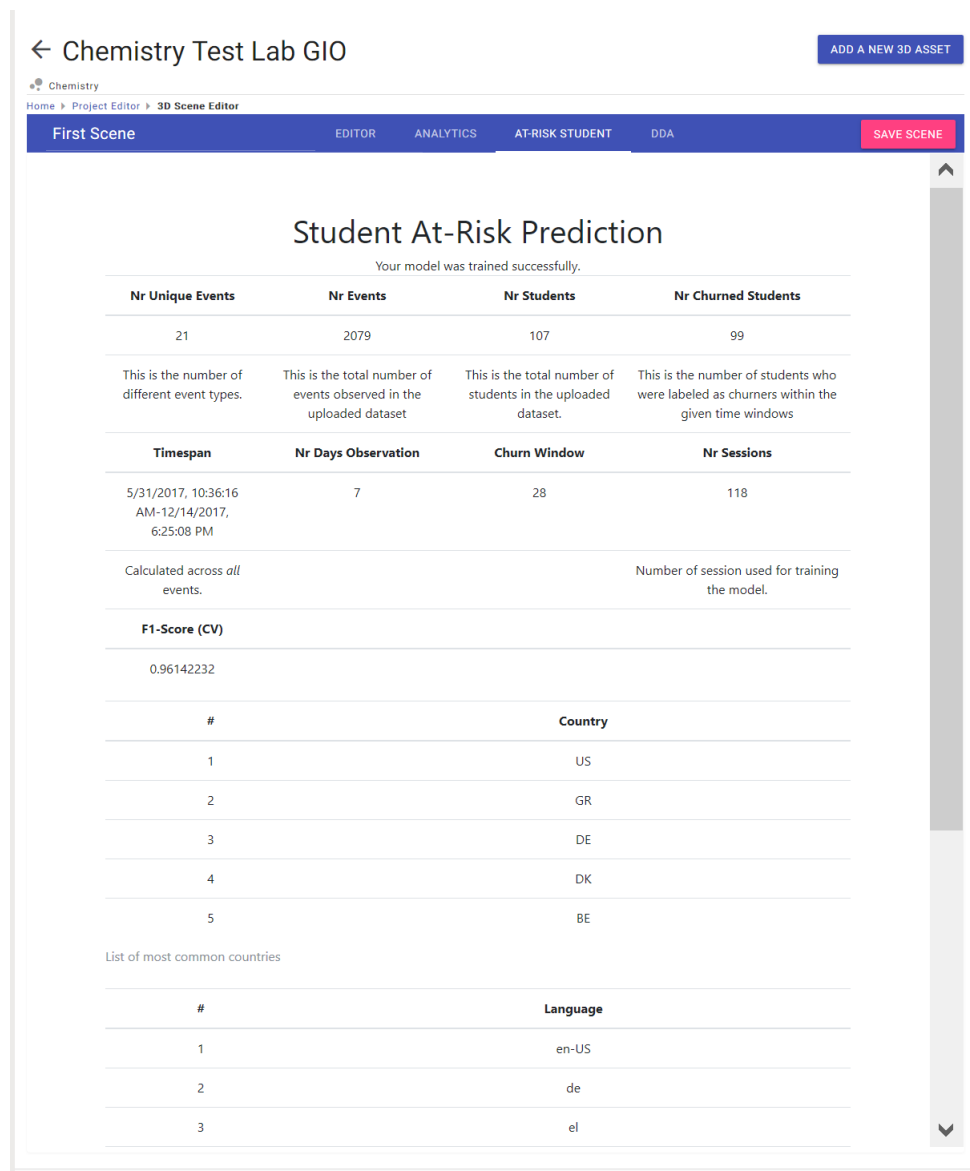


Figure 2.14: Student at Risk module.

## Content adaptation (strategies)

The last analytics module relates to content adaptation that can be accessed by clicking on the last tab of the scene editor toolbar (DDA) as seen in Figure 2.15.

The screenshot displays the 'All Strategies for Content Adaptation' page. At the top, there is a navigation bar with 'First Scene' selected and tabs for 'EDITOR', 'ANALYTICS', 'AT-RISK STUDENT', and 'DDA'. A 'SAVE SCENE' button is visible in the top right. The main content area features a title 'All Strategies for Content Adaptation', an 'Add Strategy' button, and a search bar. Below this is a table with the following data:

Name	Active	Counter	Max Count	Weight	Max Weight	Actions
difficult1	0	0	0	0	-	test
short1	1	8	200	0.5	-	test
short2	1	4	100	0.5	-	test

At the bottom of the table, it says 'Showing 1 to 3 of 3 entries' and includes 'Previous', '1', and 'Next' navigation options.

Figure 2.15: Strategies generation for content adaptation.

The call to render this module successfully sends the following values to the Goedle.io API:

**email:** The user WordPress e-mail which he registered with.

**pwd:** The second password that was generated when registering, also known as the Goedle password.

**app\_key:** The app key that was created when the user created a new lab.

### 3. Chemistry lab authoring and playing

#### 3.1 Lab authoring

This section describes the authoring tool in the context of authoring a Chemistry Lab.

##### Step 1: Register and Login

Register and login at <https://envisagelabs.itl.gr>

##### Step 2: Create a Game Project

The first step of making a lab is to create a Lab Project. Upon login, the interface depicted in Figure 3.1 is automatically presented. The *Lab Project Manager* is the central interface for creating a project or editing/deleting an existing one. A new Lab Project can be created with the interface shown in the right part “New game project” by entering a custom title and clicking on the “Chemistry” radio button which defines the template to be used for the new project. A game project can be deleted or edited with the interface on the left. Pressing the trash bucket the project is deleted. By Pressing on the project name, the project can be edited. The administrator can see all authors’ projects, whereas an author can see only its own labs.

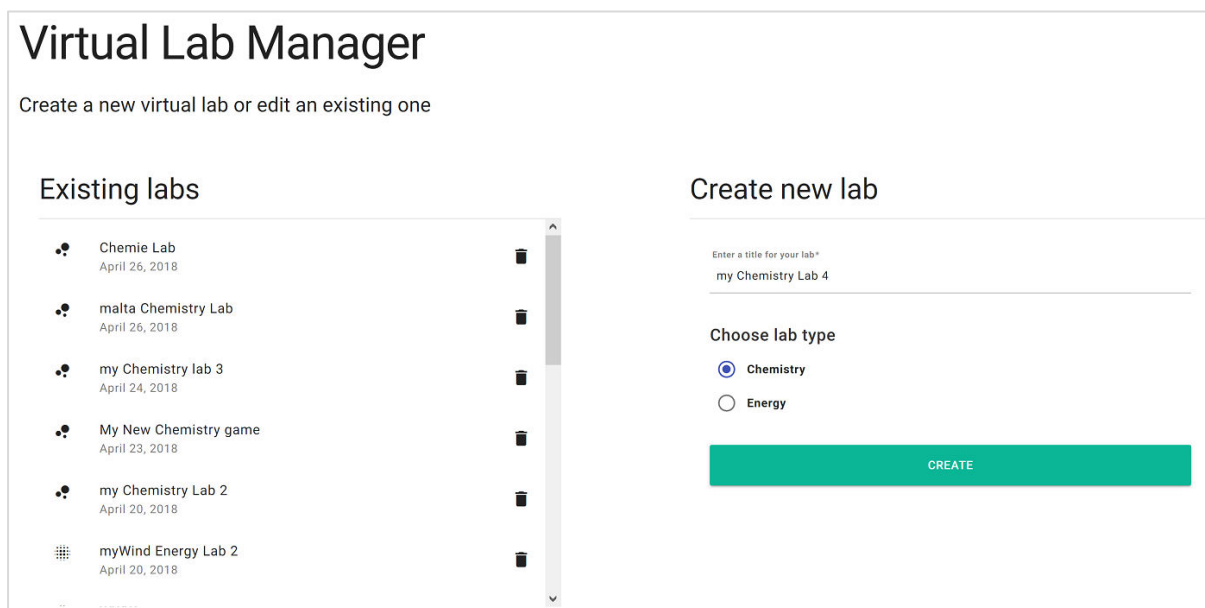


Figure 3.1: The lab project manager allows to view existing labs (left-side) or make a new one (right-side).

After creating a lab project, the interface as depicted in Figure 3.2 is shown. It presents two different types of tiles: The upper tiles with blue background represent the scenes of the lab whereas the lower tiles with pink background represent the available assets in the lab (assets created from administrator that are available for every Chemistry lab). A Chemistry Lab Project consists of 5 scenes by default, namely the Main Menu, Credits, the First Scene (typically a wander around scene that contains lots of Exams), the Exam 3D construction puzzle scene and the Exam 2D naming puzzle scene, where the latter three are the educational scenes of the lab. Apart from the shared Assets (which can’t be edited/deleted by any user apart from the administrator), the user can add new assets with the process described in the next steps.

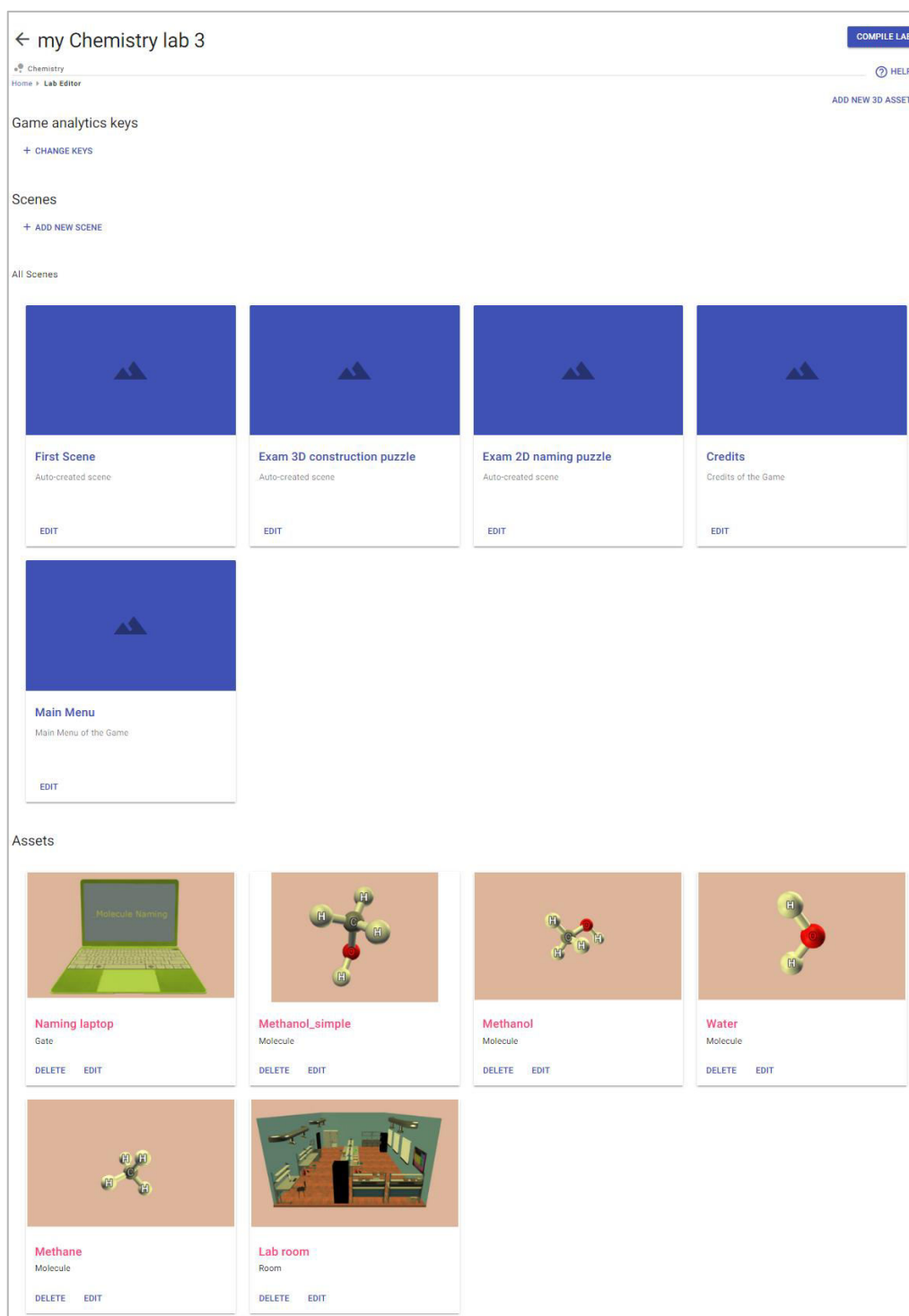


Figure 3.2: Project Editor allows to manage scenes and assets.

### Step 3: Create Assets (Optional)

Although the shared assets provide a basis to start immediately with scene editing, some educators may wish to add their own assets. In this step we will describe how an Asset can be created. In order to create shared assets across all Chemistry labs (not only the current one), administrators must create those assets at the lab project called “Chemistry joker” by following the same procedure.



**Adding a Room Asset:** Assets like “Room” are scenes very useful for the “Lab” creation, like the “First Scene” that is automatically created (as described previously). They are the physical places where the learners can wander around and participate in Exams. To add a room, press “Add new Asset” as shown in Figure 3.2 and select the option “Room” in the category dropdown widget in the Asset Creator page (Figure 3.3). Among several fields that will popup, insert the 3D model on the right side of the page by uploading the necessary files from your device. The 3D model format supported is the Wavefront Obj format that consists of an mtl (material) file that contains color and texture information, an obj file that contains geometric model of the object shape, and jpg file (or multiple jpg files) that consist of the texture of the model. Additionally, in this second prototype we support also png file format for textures that allows one to give transparency in 3D models with low computational cost. Apart from uploading those files from your local device, existing 3D models from the shared assets can be used to create a duplicate private asset for the current lab.

After the 3D model is loaded in the preview window, press “Create a screenshot” to make an icon for your asset, and finally after adding a short description, press “Create Asset” to insert the asset in the project’s database.

The screenshot shows the 'my Chemistry Lab 2' Asset Manager interface. At the top, there is a breadcrumb trail: Home > Project Editor > Asset Manager. The main heading is 'Create a new asset'. Under 'Select a category', the 'Room' option is selected, with a sub-label 'Chemistry Asset Type (Room)'. The 'Information' section has a title input field containing 'myLabRoom' and a description input field with the placeholder 'Add a small description for your asset'. Below the description field are two buttons: 'FETCH DESCRIPTION FROM WIKIPEDIA' and 'FETCH DESCRIPTION FROM EUROPEANA'. The 'Object Properties' section has a radio button selected for 'MTL & OBJ files'. The 'Object Preview' section shows a 3D rendering of a chemistry lab room. Below the preview is a 'Select an asset to insert' section with four thumbnails of molecular models. Below that is a file selection area with a 'Browse...' button and the text 'No files selected.'. At the bottom, there is a 'Screenshot' section with a small 3D preview and a 'CREATE SCREENSHOT' button.

Figure 3.3: Creating a Room asset for the Chemistry lab.

**Create a Gate:** Gates are objects that placed in a scene in order to load another scene (like portals). In the Chemistry lab template for example, the laptop is a gate because it loads an Exam scene. By selecting the option “Gate” in the category dropdown widget in the Asset Creator page (as shown in Figure 3.4), you can create a Gate, which in our case is a laptop model.

← my Chemistry Lab 2

The screenshot shows the 'Asset Manager' page for 'my Chemistry Lab 2'. The 'Create a new asset' section is active, with 'Gate' selected in the category dropdown. The 'Information' section has 'Laptop' entered as the title. Below the title are two buttons: 'FETCH DESCRIPTION FROM WIKIPEDIA' and 'FETCH DESCRIPTION FROM EUROPEANA'. The 'Object Properties' section has 'MTL & OBJ files' selected. The 'Object Preview' section shows a 3D model of a laptop with 'Molecule Construction' on the screen. Below the preview are four thumbnails of molecular models. At the bottom, there is a 'Screenshot' section with a 'CREATE SCREENSHOT' button.

Figure 3.4: Creating a Game asset (laptop) that allows from a Lab scene to load an Exam scene.

**Create a molecule:** In order to add a Molecule, select the corresponding category in the dropdown widget as shown in Figure 3.5. Provide the name and formula of the Molecule as a string (text). Atom names with two letters should be written as follows: the first letter should be capital but the second letter should be written with low case, e.g. NaCl. The Protein Database Format (PDB) is supported for uploading molecules<sup>8</sup>.

<sup>8</sup> <https://www.cgl.ucsf.edu/chimera/docs/UsersGuide/tutorials/pdbintro.html>

## ← my Chemistry Lab 2

Chemistry

Home > Project Editor > Asset Manager

Create a new asset

Select a category

Molecule

Chemistry Asset Type (Molecule)

Information

Enter a title for your asset \*

Add a small description for your asset

FETCH DESCRIPTION FROM WIKIPEDIA

FETCH DESCRIPTION FROM EUROPEANA

Molecule Options

Chemical Type (e.g.: H<sub>2</sub>O)

Functional Group

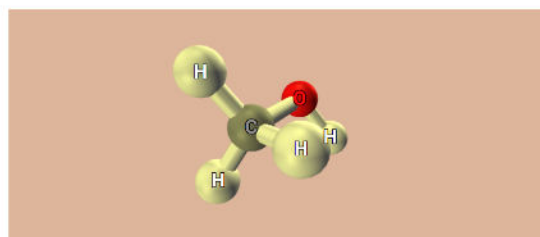
Select a functional group

Fluid Options

Object Properties

Protein Data Bank file

Object Preview



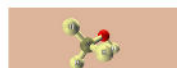
Select an asset to insert



Select a pdb file

Browse... No files selected.

Screenshot



CREATE SCREENSHOT

Figure 3.5: Creating a Molecule Asset to be used in the Exam scenes of the Chemistry lab.

### Step 4: Modify Scenes

The assets should be placed inside a scene in order to enrich the scene with content. The minimum requirement for the scene to be functional is that a room should be placed. Go to the “Project Editor” as shown in Figure 3.6. Initially, 5 “scenes” are available by default: a) a 3D scene where the lab takes place (called “First Scene” by default), b) an Exam 3D construction puzzle scene, c) an Exam 2D naming puzzle scene, d) the main menu scene and e) the credits scene. A scene can be also deleted by pressing the corresponding delete button in the bottom of a scene tile in the Project Editor as long as it is not one of the default 5 aforementioned scenes, i.e. only additionally created scenes can be deleted. A scene can be deleted by pressing the “DELETE” button in the bottom of the respective scene tile.

Click on the “edit” button of the “First Scene” in order to edit it. A 3D editor will pop up as the one presented in Figure 3.6. In order to edit the title and the description of the scene change the title in the ribbon and the description text below the ribbon, respectively. Then press “SAVE SCENE”. The button will change color twice and the scene will be saved.

#### Step 4.1: Editing the 3D Lab scene

The 3D lab scene can be edited with the 3D editor as shown in Figure 3.6. Drag’n’drop from

the right panel into the 3D environment is possible e.g. a Room asset and a Gate (laptop) asset inside the first one. Use the widget to fix asset’s position, rotation, scale and link Exam scenes by using right mouse click (only for Gates) as shown in Figure 3.7.

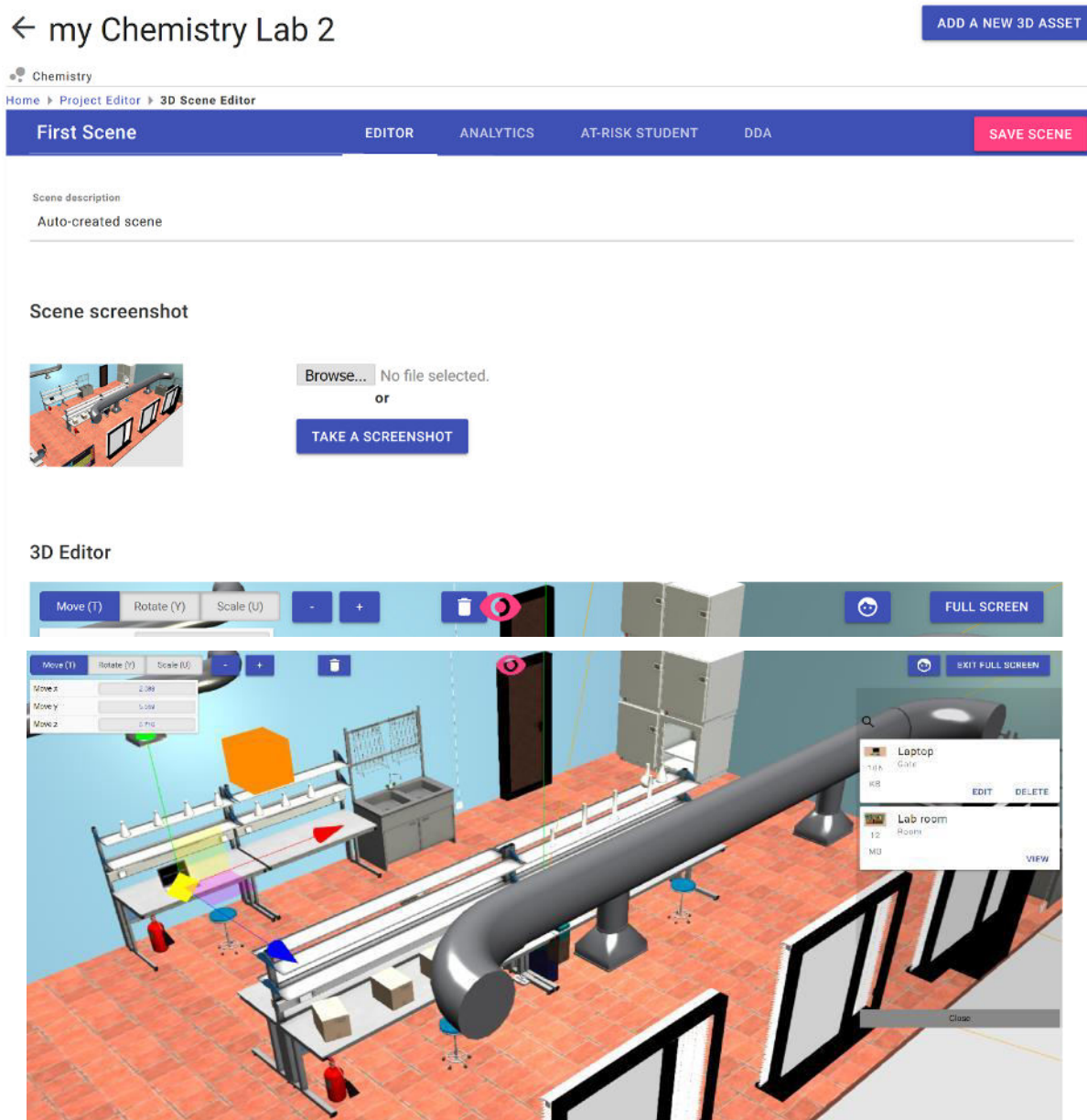


Figure 3.6: The 3D editor for editing the Room scenes.

The properties of 3D models can be changed by right clicking on them as shown in Figure 3.7. In the Lab scene, only the laptop (Gate) has a property that can be modified. Explicitly, the property to be modified concerns the Exam scene to be loaded. Two options are available, namely the Exam 2D naming puzzle scene, and the Exam 3D construction scene. In the following we describe how to modify the Exam scenes.

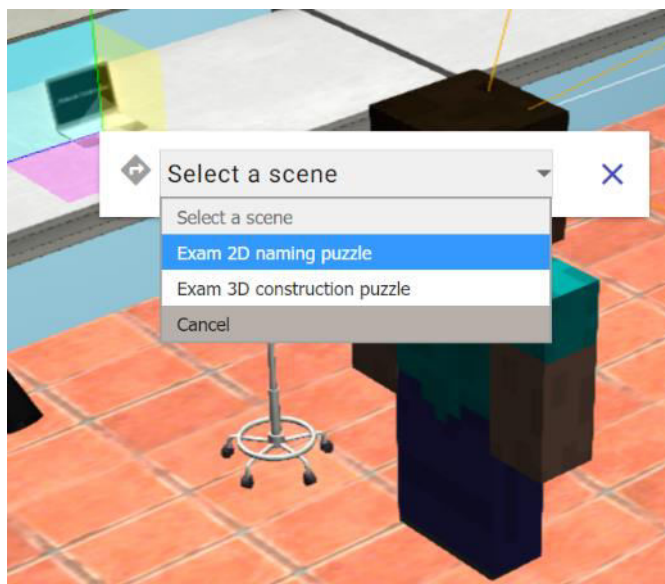


Figure 3.7: Change the properties of the laptop (Gate) by right mouse click in order to link in an Exam scene.

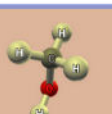
#### Step 4.2: Exam Scenes

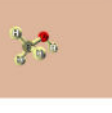
To create specific exams that contain questions regarding molecules, you can edit the default “Exam 3D construction puzzle scene” and “Exam 2D naming puzzle” scenes, or create a new one. As shown in Figure 3.8 you can add Molecules that will transform in to exam’s questions by drag’n’drop them at the “Molecule Selector” area. All the Molecules that created before as project assets, will be available for selecting.

Exam 3D construction puzzle


**Molecule selector**


Select molecules to insert them into the Exam. The active molecules order dictates the sequence of appearance in the Unity game.

  
 Methano\_simp...

  
 Methanol

**Available molecules**

  
 Water

  
 Methane

SUBMIT CHANGES

Figure 3.8: Adding molecules in an Exam scene.

## Step 5: Observe game analytics

Game analytics are incorporated in the “First Scene”, which can be accessed through the Project Editor with “Edit” button. By pressing the “Analytics” tab in the blue ribbon as shown in the interface of Figure 3.9, the analytics of the Chemistry lab appear. On the left side, the distribution of students into the PISA categorization is shown according to their achieved score, which is actually the molecules completed in naming and 3D construction exam. On the tables, the achieved molecules are shown per user (an anonymous code is used as an id).

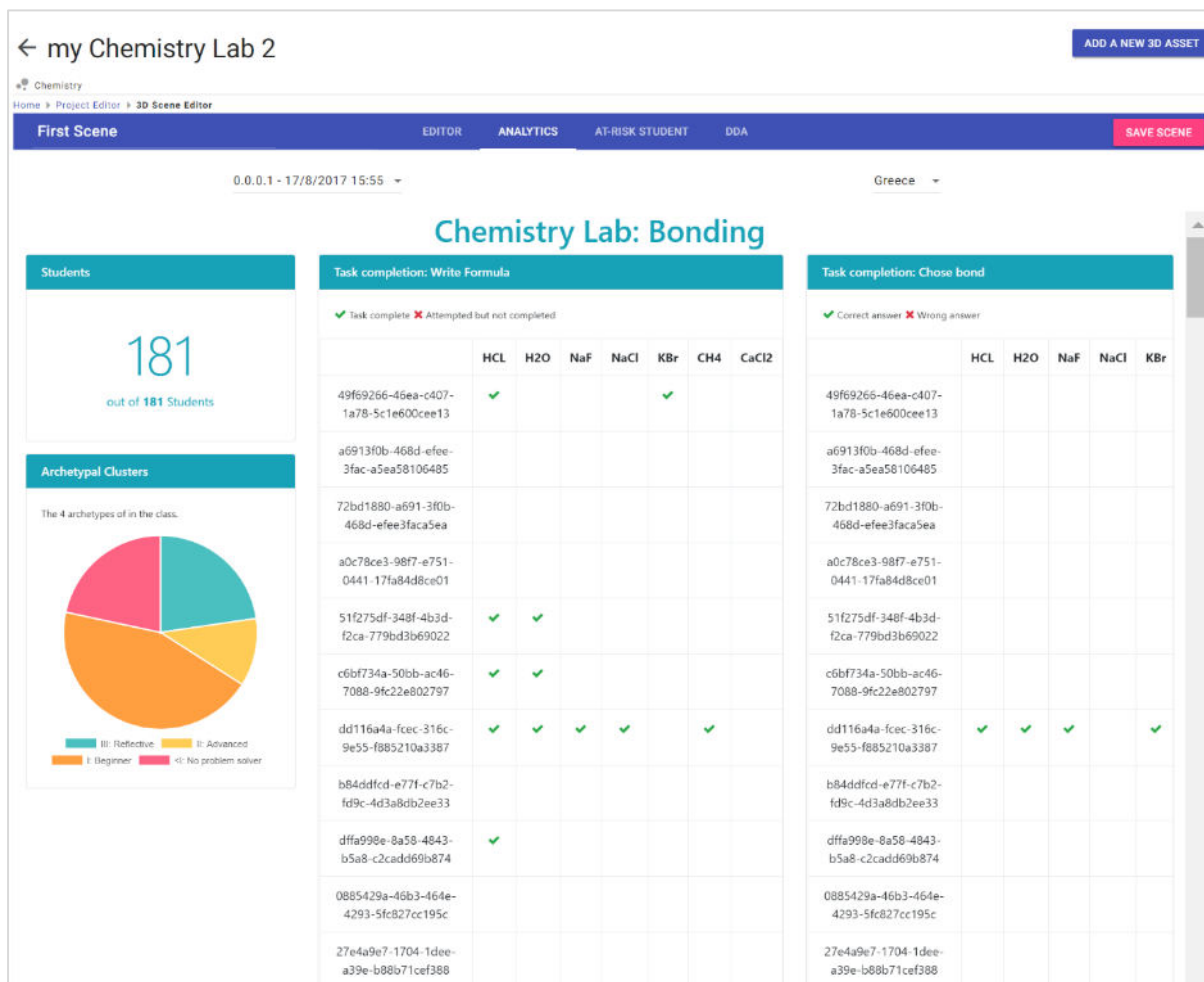


Figure 3.9: Observing analytics for the chemistry lab inside the authoring tool.

The third tab named “Student-at-risk” present the statistics regarding: a) the number and type of events tracked in the lab in order for the teacher to realize the volume of the data; b) the number of students who played the lab; c) who left the lab (churned); d) the timespan where the data was gathered and other statistics that explained in the deliverables of WP2 [1] and WP3 [2].

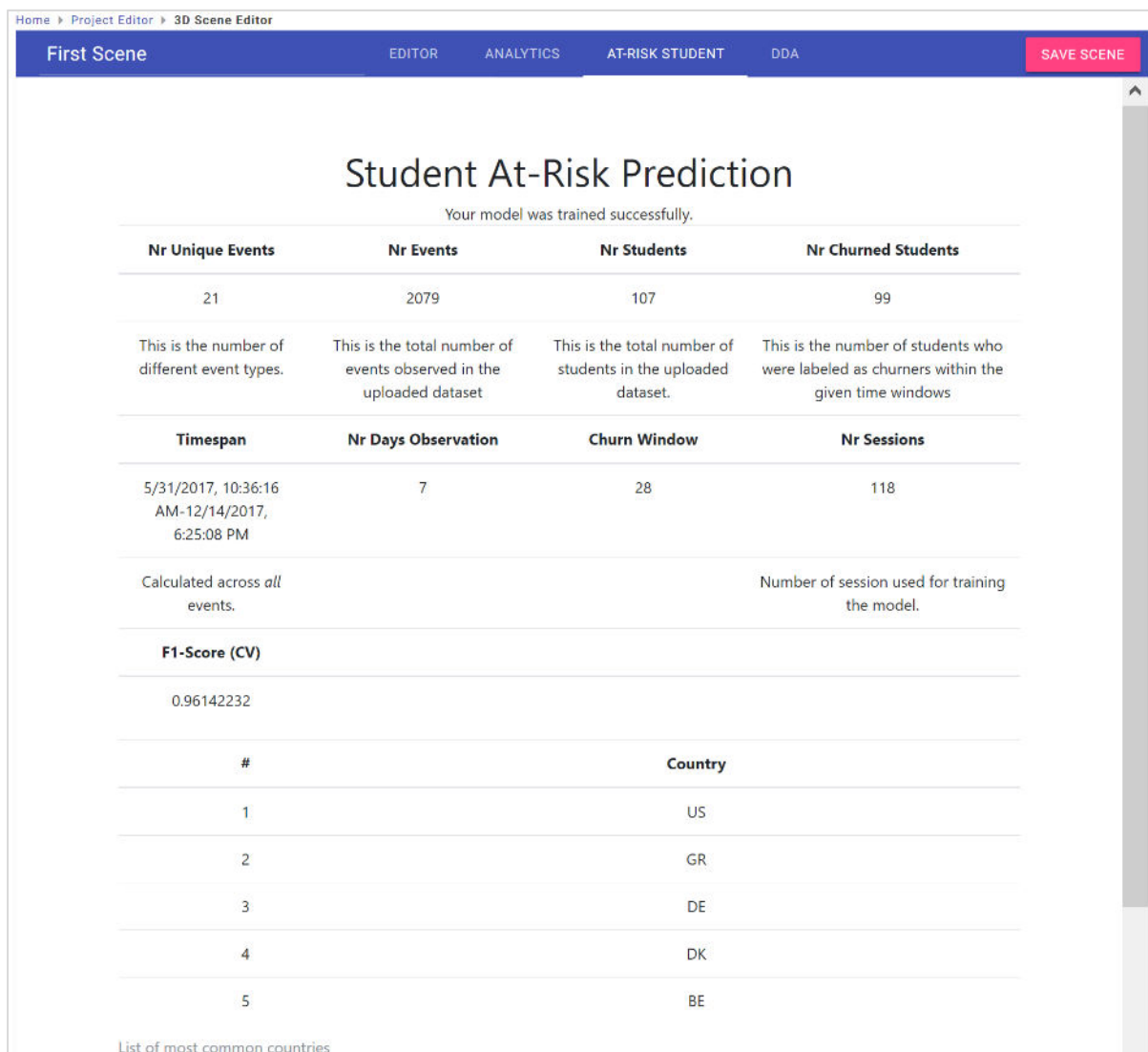


Figure 3.10: Student-at-risk tab shows the shallow analytics.

### Step 6: Make Strategies

The educator can change the molecules that appear in the exams without re-compiling and re-deploying the labs by using the strategy-making tool. A strategy is a list of molecules that are a subset of the molecules of an Exam scene. In this manner, many strategies can be made and compared. In Figure 3.11, the interface for making a strategy is shown. In Figure 3.12, the strategies can be observed in a list. The counter, max counter and weight variables show to how many users the strategy is deployed or it is going to be deployed to.



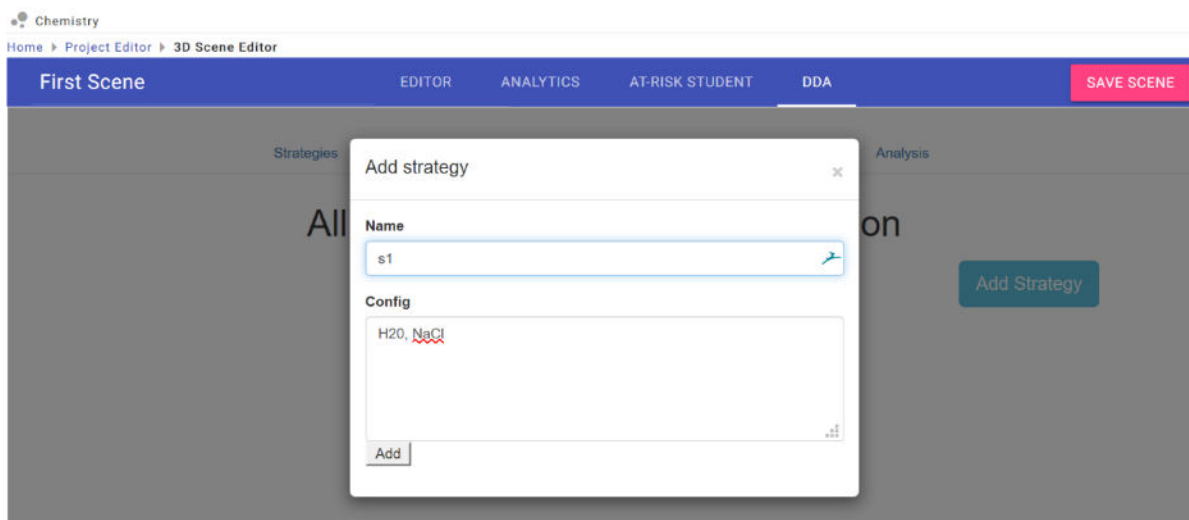


Figure 3.11: Making a strategy for the Chemistry lab.

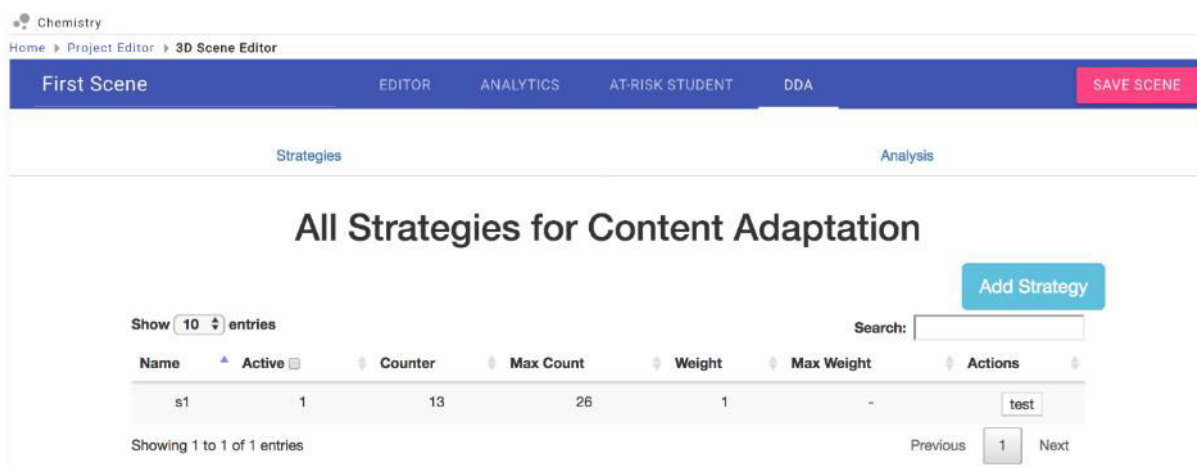


Figure 3.12: Observing strategies for Chemistry lab.

## Step 7: Compile and disseminate

In order to compile and deploy the lab, the “Compile Lab” button in the Project Editor should be used as shown in Figure 3.13. Windows, Linux, Mac and Web platforms are fully supported for compiling. The compiling lasts about 5 minutes. A link is provided in the end to download the lab or play it directly with the web browser if it is compiled for Web.

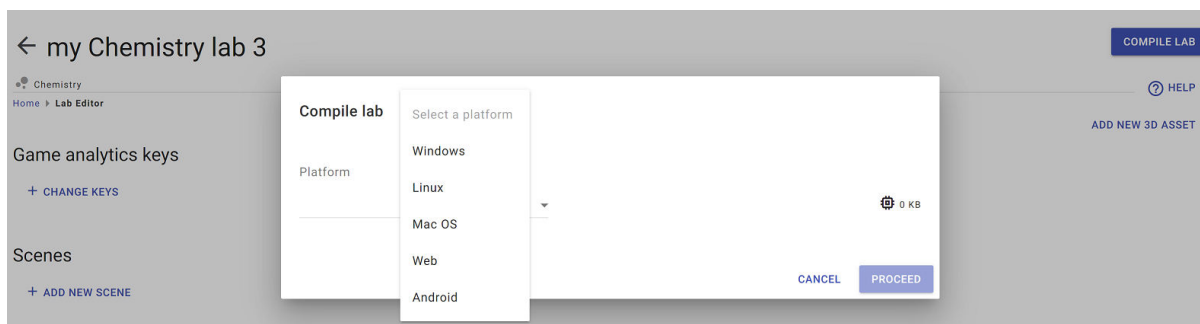


Figure 3.13: Compiling options for the Chemistry lab.



## 3.2 Lab playing

This section provides instructions on how to play the lab, although it is self-explainable, for the needs of this deliverable.

### **Step 1: How to run the lab**

The generated lab is provided through a web link. A precompiled version can be found in

[https://envisagelabs.itl.gr/games/ChemistryLab\\_v2.0/](https://envisagelabs.itl.gr/games/ChemistryLab_v2.0/)

### **Step 2: How to start playing**

When you first open the labs, the lab menu screen is presented as shown in Figure 3.14. Here you can choose from a list of available buttons such as Login, Help (Tutorial), Enter. To start playing press on the Enter button in the bottom of the screen.



Figure 3.14: The main menu of the lab.

### **Step 3: Wonder around in the lab**

Before start playing, an image is displayed as shown in Figure 3.15, providing information about controlling the movement of the lab character as well as the goal of the lab. Subsequently, the player is transferred to the Lab scene (Figure 3.16) where he can wander around and interact with objects. Moving around is available through the use of WASD keyboard buttons and camera rotation through mouse panning. After the player gets familiar with the movement controls, he/she must search for the two available laptops (Molecule Naming, Molecule Construction) that open a chemistry quiz game. To interact with the laptops the player must be in a close proximity to the laptop and press the “e” on the keyboard (a tooltip is highlighted on the lab, see Figure 3.17).



Figure 3.15: The information clipboard when you first enter the “Lab” scene.



Figure 3.16: The “Lab” scene where the player can wonder around.

#### Step 4: Molecule naming 2D Puzzle

When the player has interacted with the laptop displaying the title “Molecule Naming” as shown in Figure 3.17, the relevant quiz will initialize and the respective lab scene will be loaded. In this 2D puzzle quiz, the goal is to provide the chemical formula for the molecule displayed in the top of the screen. To do so, the player can left click on the chemical elements pieces (White Square shapes) and, by holding the left button down and dragging the mouse, he can move the element around in any direction (Figure 3.18).

For a successful formula completion, specific elements must be placed in the element slots (metal square shapes in a yellow panel) in a correct order. To place an element, it must be moved upon the slot, and if the element-slot matching is correct, when the left mouse

button is released, the element will be placed inside the slot and locked from any further interaction. In case the matching is wrong it will return to its initial position after the mouse release, followed by an error sound. If all the slots are filled, then the formula naming process is completed and the “Next” button (bottom right corner) becomes highlighted. In order to name another molecule’s formula, the player must click on the “Next” button independently of the current molecule’s formula completion process. To exit the lab the player can just press the “exit” button (top right corner) and return to the “Lab” scene.



Figure 3.17: The laptop that transfers the player to the “Molecule Naming” lab quiz.

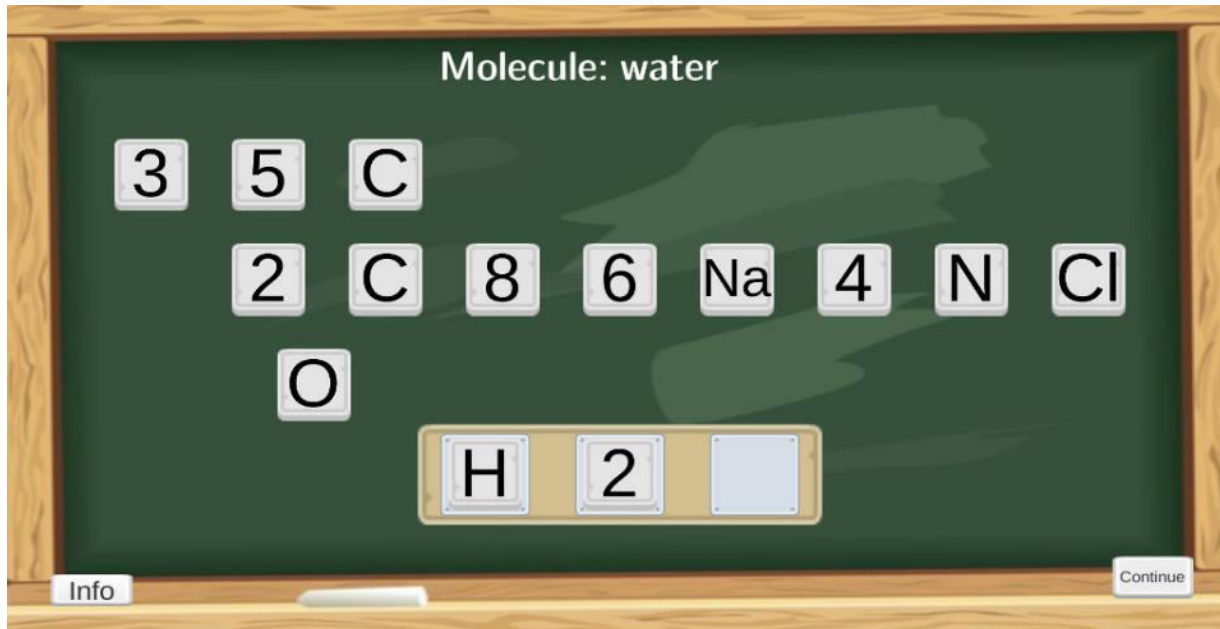


Figure 3.18: The interface of the “Molecule Naming” quiz.

### Step 5: Molecule 3D Construction Puzzle

The other option for the player is to play the “Molecule construction” quiz by interacting with the respective laptop in Figure 3.19. The main idea of this quiz is to construct the structure of the displayed molecule by placing specific elements in the transparent round



slots upon the molecule. Regarding the interface, in the top of the screen there is a list of buttons that spawn a specific element in the scene. In the bottom left corner, information about the formula and the name of the molecule are displayed.

For a successful molecule construction, the player must spawn various elements in the scene and by using the drag and drop mechanic (same as Molecule Naming quiz) fill all the slots with the correct elements. Since the molecule is a 3D object the need for movement and different perspective look is essential. Therefore, the player can rotate the molecule in all possible directions using either the right mouse click or the WASD keys on the keyboard. Last but not least, through a list of available buttons (Clear, Next, Exit) , the player can clear the scene of all the current generated elements, bring the next Molecule for construction or exit the quiz and return to the “lab” scene as shown in Figure 3.20.



Figure 3.19: The laptop that transfers the player to the “Molecule Construction” lab quiz.

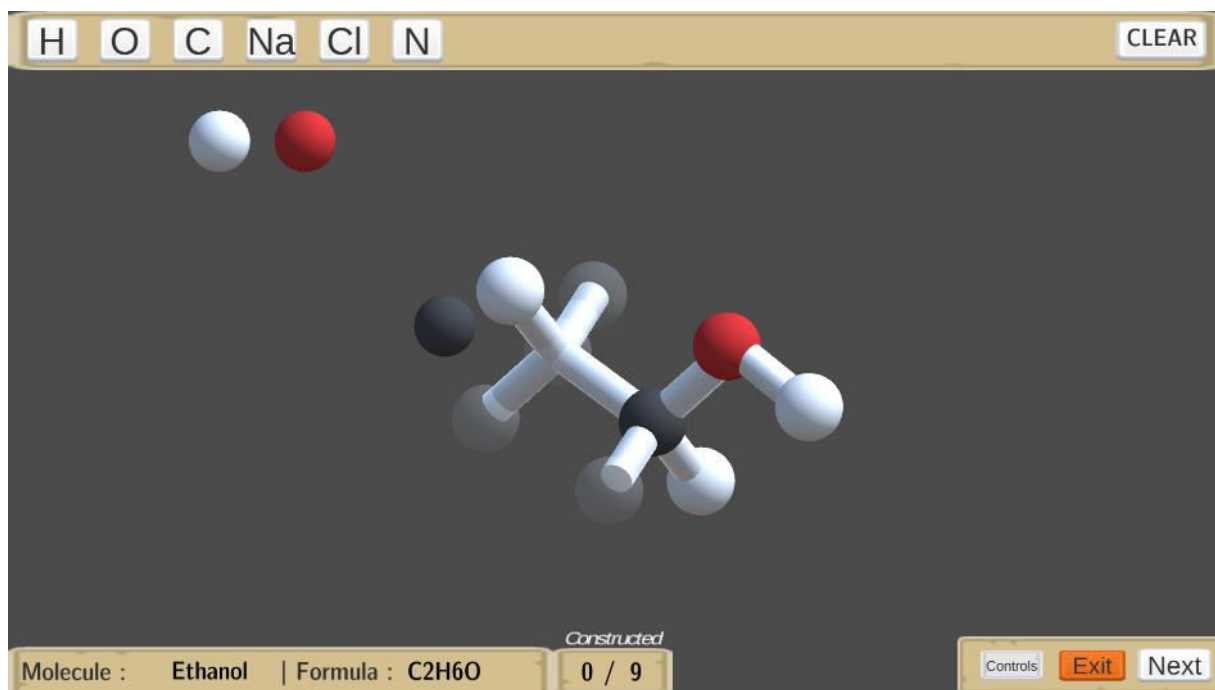


Figure 3.20: The interface of the “Molecule Construction” quiz.

### Step 6: Additional features

A list of various objects such as boxes, pipettes, lab tables, computers and flasks give a realistic feel and look to the lab which is close to a real life chemistry lab. Also, the use of safety signs is present teaching the players about the precautions and safety practices that must be followed while inside a chemistry lab as shown in Figure 3.21.

Lastly, when the player exits the lab through the main door, a validation clipboard appears which displaying a detailed review of the exercises that the player completed. Also, a rating through a list of badges is given to the player based on his performance on the exercises. The player can either exit or continue to increase his score and get a better rating.

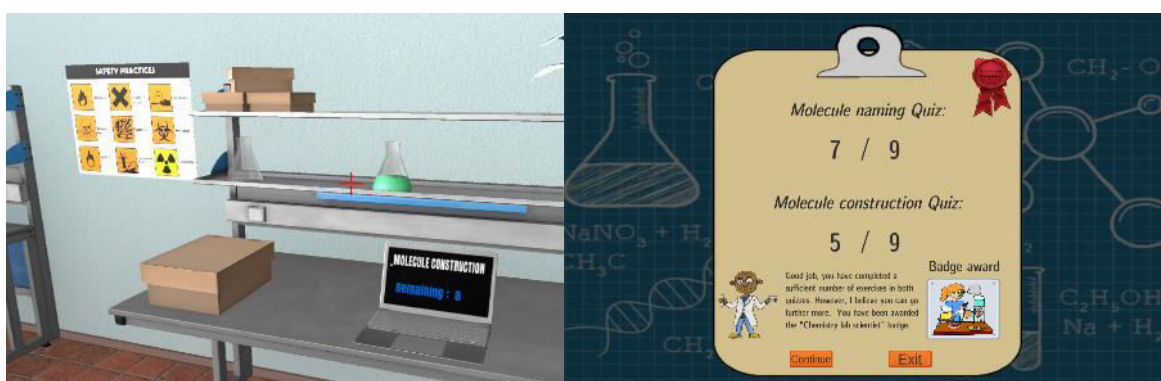


Figure 3.21: Safety signs (left image), the player’s rating screen.

## 4. Wind Energy lab authoring and playing

### 4.1 Lab authoring

This section describes the authoring tool in the context of authoring a Wind Energy Lab.

#### **Step 1: Register and login**

Register and login at <https://envisagelabs.iti.gr>. The Lab Project Manager should appear as shown in Figure 4.1.

#### **Step 2: Make a new Lab Project**

The first step towards making a lab is to make a Lab Project. Upon login, the interface depicted in Figure 4.1, namely the “Lab Project Manager” is automatically presented. The *Lab Project Manager* is the central interface for creating a project or editing/deleting an existing one. A new Lab Project can be created with the interface shown in the right part under the label “Create new project” by entering a custom title and clicking on the “Energy” radio button that defines the template to be used for the new project. A lab project can be deleted or edited with the interface on the left. Pressing the trash bucket the project is deleted. By Pressing on the project name, the project can be edited. The administrator can see all authors’ projects, whereas an author can see only its own labs.

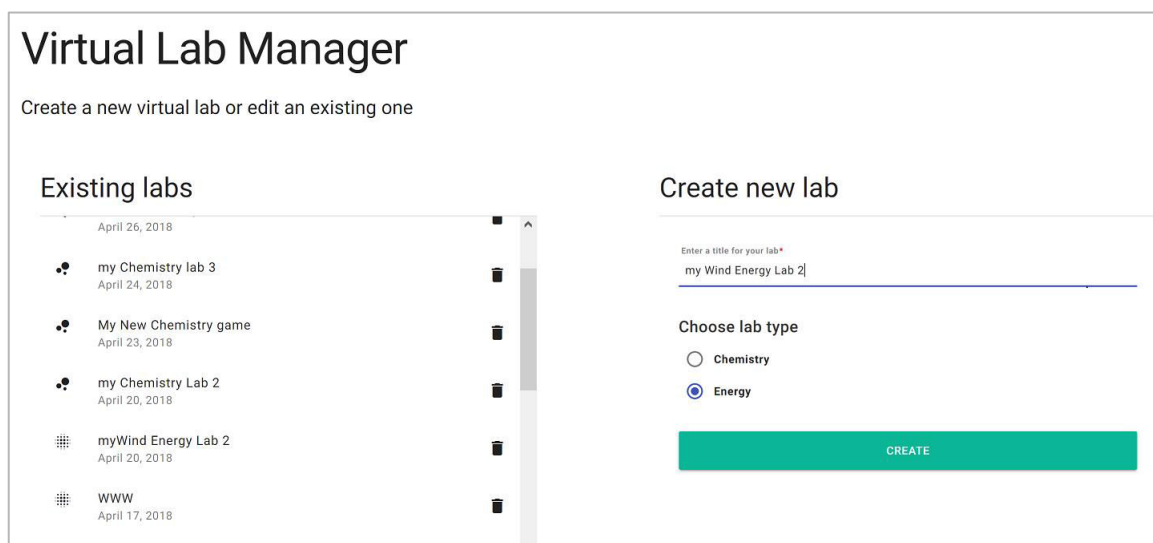


Figure 4.1: Making a new Wind Energy Lab.

After creating a lab project, the interface of the “Project Editor” appears as shown in an interface depicted in Figure 4.2. It presents in the upper part the default scenes of the project with blue tiles, and also the shared Assets by the administrator available with pink tiles in the bottom part. A Wind Energy project consists of 5 scenes by default, namely the Main Menu, Credits, the First Scene, the Mountains, the Seashore and the Fields scenes, where the latter three are the educational scenes of the lab. Apart from the existing Assets, the user can add new assets with the process described in the following.

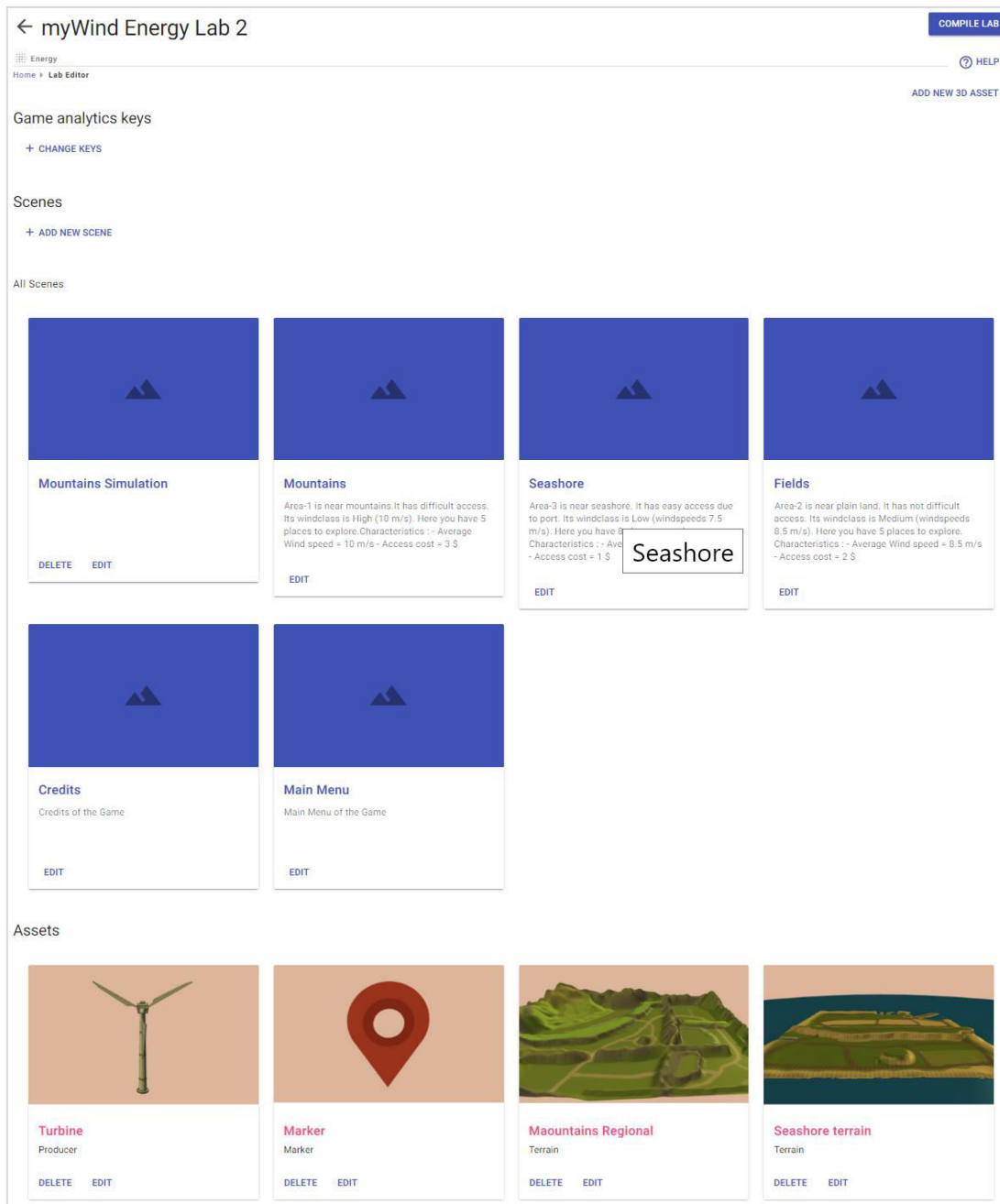


Figure 4.2: The “Project Editor” contains default scenes and assets available.

### Step 3: Making new Assets (optional)

The process of making new assets is optional because the assets are already shared by the administrator. The way to share assets is to make assets for a certain lab named as “Energy-Joker” lab. The assets of this lab are visible and usable from all projects. All assets made inside other projects are only visible to these certain projects.

What we need for an energy lab are five types of assets, namely a terrain, wind turbines that produce energy (producer), buildings (consumers) that consume the produced energy (consumer), decorative assets and markers that can connect two scenes. To add a new asset press “Add new 3D Asset” button in the project editor. Then, the interface of Figure 4.3 is shown where the user is prompted to select the category of the asset. In the following, we describe the actions to be done according to the type of asset to be created.

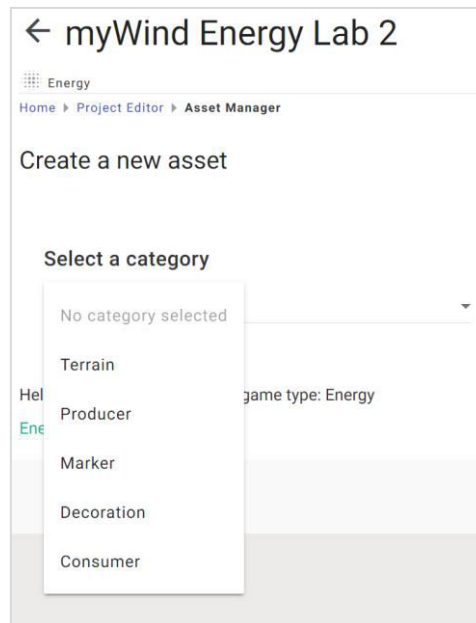


Figure 4.3: Menu for selecting the category of the asset to be created.

**Adding a terrain:** By selecting the option “Terrain”, several fields will pop up as shown in Figure 4.4. Every Asset should have a 3D model that is its representation in the lab. The 3D model format supported is the Wavefront Obj format that consists of an mtl (material) file that contains color and texture information, an obj file that consists the coordinates of the geometric shape of the model, and an image file of jpg or png format that consist of the texture of the model. Uploading the mtl, obj, and the jpg for texture. Note that multiple images can be selected for the texture model. There are also sample files provided by the tool to the author, available since the project creation. To make an icon for your asset, go to the 3D model preview window, zoom in-out with the mouse and press “Create a screenshot”. Then scroll down to see more fields for the Terrain. After setting all the parameters press “Create Asset” to insert your asset in the authoring tool database, so as to make it reusable in the current project.



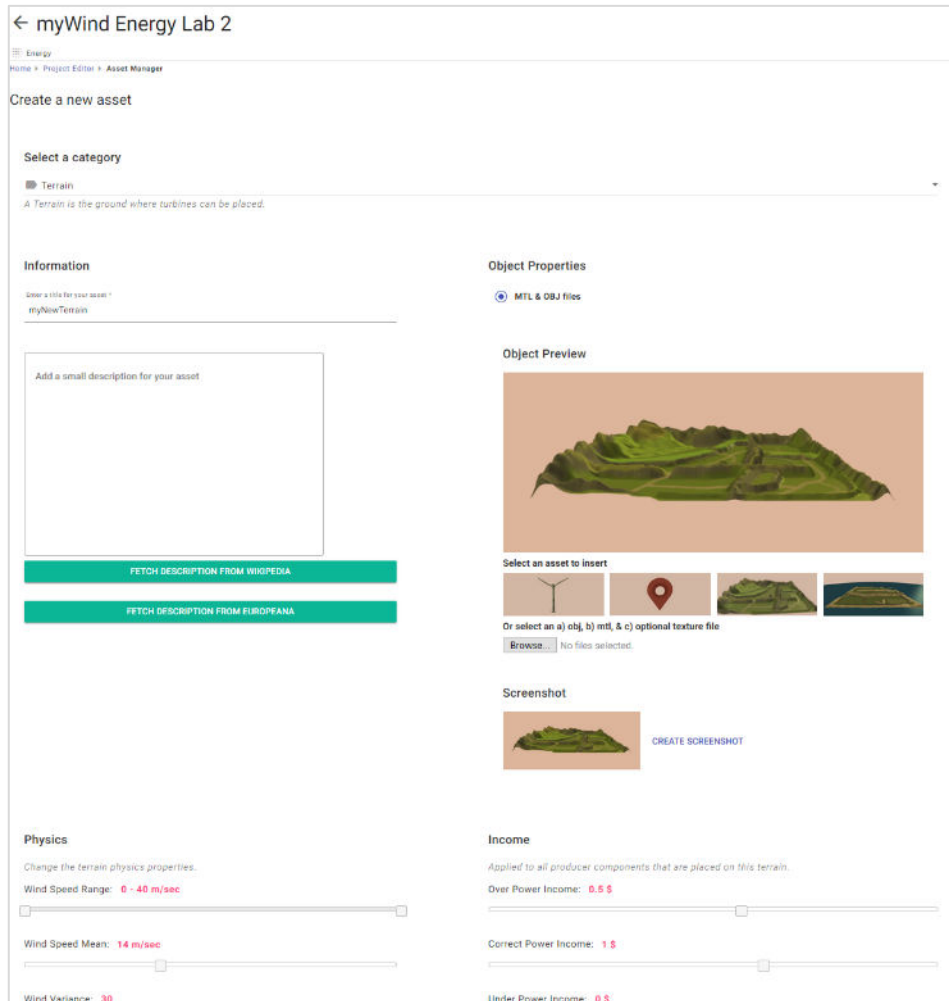


Figure 4.4: Creating a terrain asset.

**Add a decoration:** If the “Decoration” option is selected, the interface that will popup is similar to the terrain (Figure 4.4) without the fields in the bottom, i.e. the decoration has only title, description, and 3D model. The decoration can be anything to be placed in the Terrain such as trees, boats, etc. that increases its quality. They do not have any functional properties during the experience of the virtual lab.

**Create a building (consumer):** For the building, you need to choose the “Consumer” category as the building is a consumer of energy. Then, the form will expand showing more fields as shown in Figure 4.5. The fields that should be filled are: a) the title of the asset, and b) the 3D files of the asset. Select an mtl and an obj file for the turbine and an image specified for texture. You can locate some 3D models at the bottom. Rotate the presented 3D model in a satisfying pose and press “create screenshot” to generate an icon for the asset for the selected pose. Leave the building’s properties, i.e., the energy consumption range, mean and variance, to the default values.

myWind Energy Lab 2

Energy

Home > Project Editor > Asset Manager

Create a new asset

Select a category

Consumer

A Consumer is a game object that consumes energy (e.g. a building).

Information

Enter a title for your asset \*

myNewTerrain

Add a small description for your asset

FETCH DESCRIPTION FROM WIKIPEDIA

FETCH DESCRIPTION FROM EUROPEANA

Object Properties

MTL & OBJ files

Object Preview

Select an asset to insert

Or select an a) obj, b) mtl, & c) optional texture file

Browse No files selected.

Screenshot

CREATE SCREENSHOT

Energy Consumption

Energy Consumption Range: 50 - 150 kW

Energy Consumption Mean: 100 kW

Energy Consumption Variance: 50

CREATE ASSET

Figure 4.5: Creating a consumer (building) asset.

**Create a turbine (producer):** For the turbine, you need to choose the “Producer” category as the turbine is a producer of energy. The form will expand showing more fields as shown in Figure 4.6. The fields that should be filled are: a) the title of the asset, and b) the 3D files of the asset. Leave the turbine’s properties, i.e., the production efficiency depending on the wind speed, as it is.

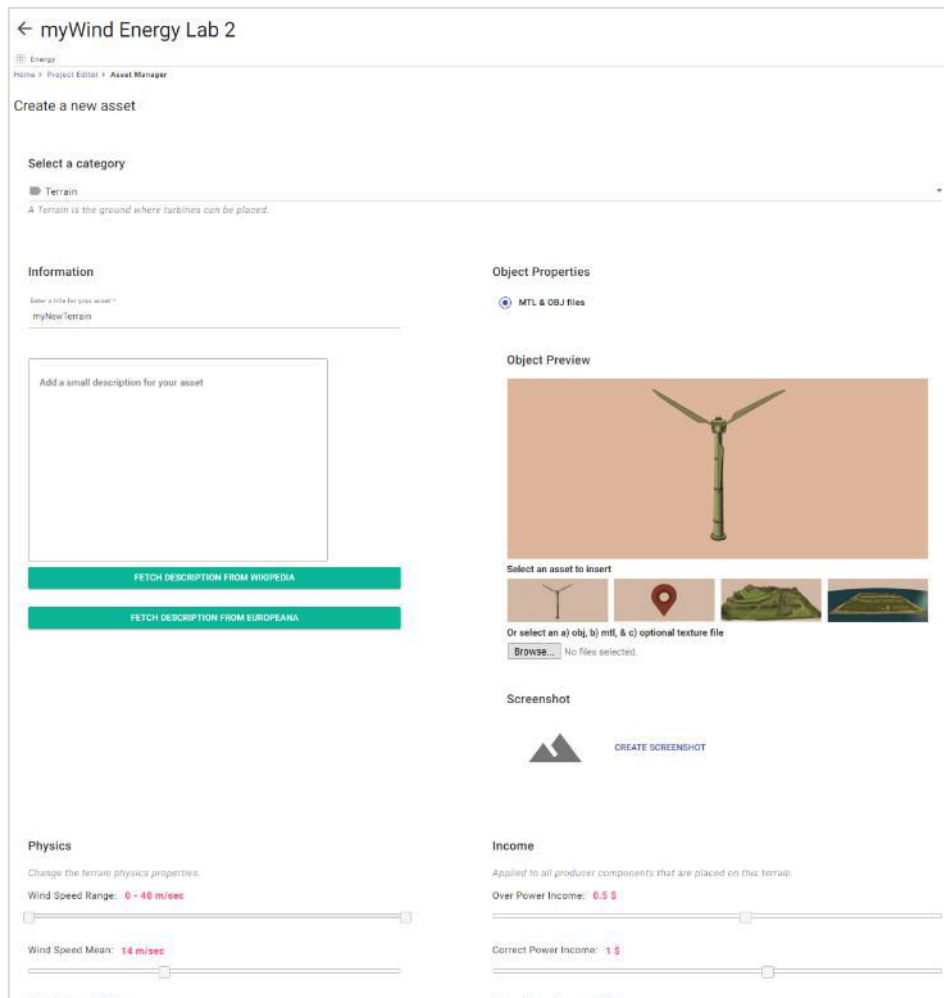


Figure 4.6: Creating a turbine (producer) asset.

**Create a Marker:** Markers are 3D model where user clicks and thus going from one Regional Scene to another Scene (a playable wind energy lab that takes place in that Region). There is no need to make a new marker. However, new markers can be created by inserting a title and a 3D model. The properties of the marker i.e. the scene to load when the marker is clicked in the lab can be changed with right click in the 3D editor.

**Step 4: Make new Scenes**

Scenes are split into Regional, i.e. scenes that contain a terrain and several markers for the first part of the lab (Mountain, Fields, Seashore). They can be created in the Project Editor with the ADD NEW SCENE button and by providing its title, description, and selecting the options “3D” and “Regional scene” in its options as shown in Figure 4.7. The “Simulation” scenes of the lab can be generated with the same way by unticking “Regional Scene” check box.

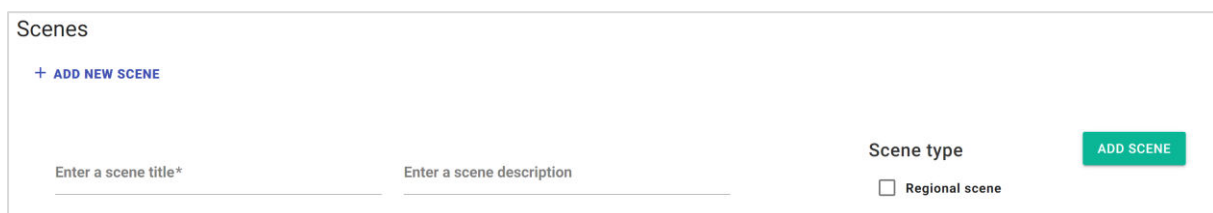


Figure 4.7: Creating a new scene for the Wind Energy lab.

### Step 5: Add Assets to Scenes

Placing assets into the scene is a necessary condition for the lab to function. Each Regional and Simulation scene can be edited by pressing edit in the corresponding tile in the “Project Editor”. Five Scenes are available by default namely the Regional scenes (mountain, seashore, field), and one Simulation scene. The standard scenes of the lab such as the main menu and the credits are also created. By clicking edit in a Regional or Simulation scene, the 3D editor as shown in Figure 4.8 is loaded.

The 3D editor consists of the following components. The upper ribbon containing the title of the scene which can be clicked and edited, the “EDITOR” button which is by default selected and shows the 3D environment of the scene, the “Analytics” button which shows the lab analytics, and the save button that saves all the changes in the scene. Below the ribbon, the description of the scene can be found and edited. The 3D environment can be used to edit the scene. The 3D environment contains the avatar, the right sidebar of available assets, and several buttons for handling the position, the rotation and the scale of the asset.

In the editor, you can drag and drop a terrain and place it in the scene. Drag and drop one wind turbine and one building after inserting the terrain. Adjust the above assets, i.e. place and move them accordingly so as they seem naturally placed on a terrain’s spot. Determine also their scale. After finishing press “Save scene”.

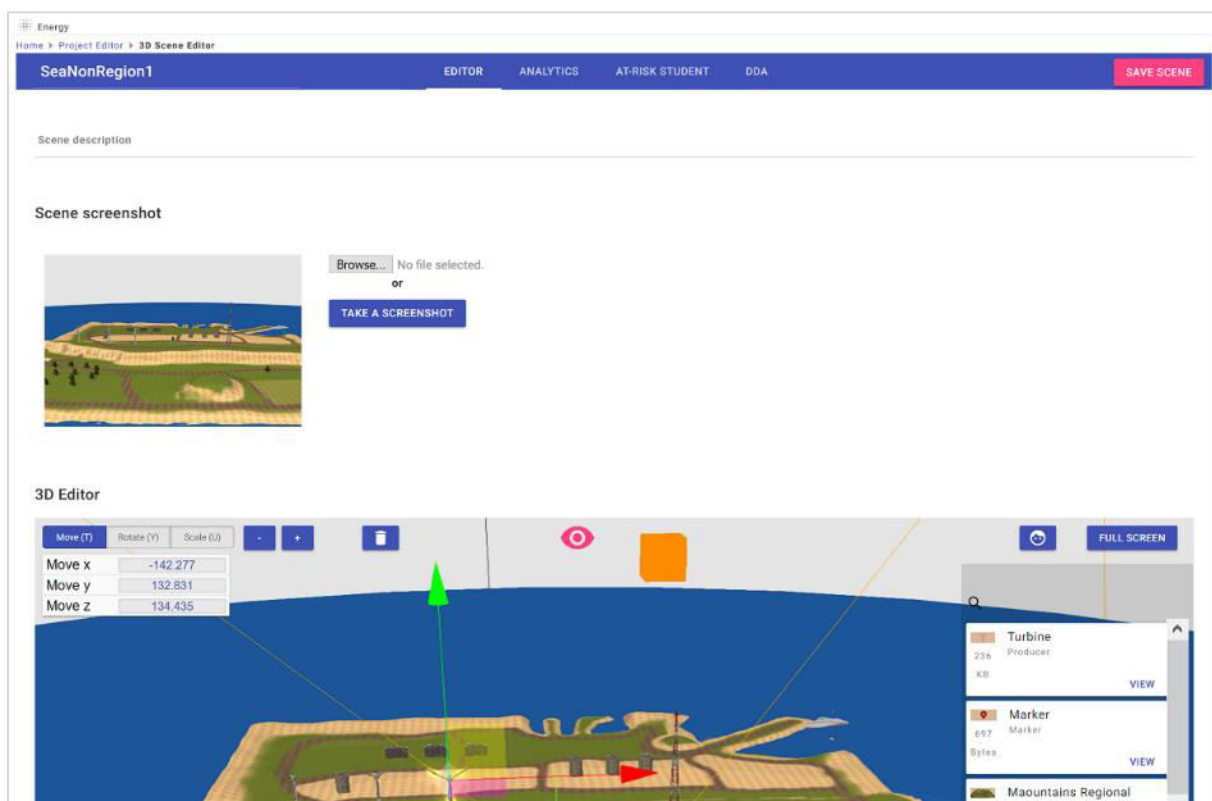




Figure 4.8: Adding assets in a Wind Energy simulation scene with the 3D editor.

In a similar manner a Regional scene can be edited. The assets to be inserted are a Terrain and several Marker assets as shown in Figure 4.9. By right clicking on the Marker, the Simulation scenes associated with the marker will be shown. Select one of them and press Save.

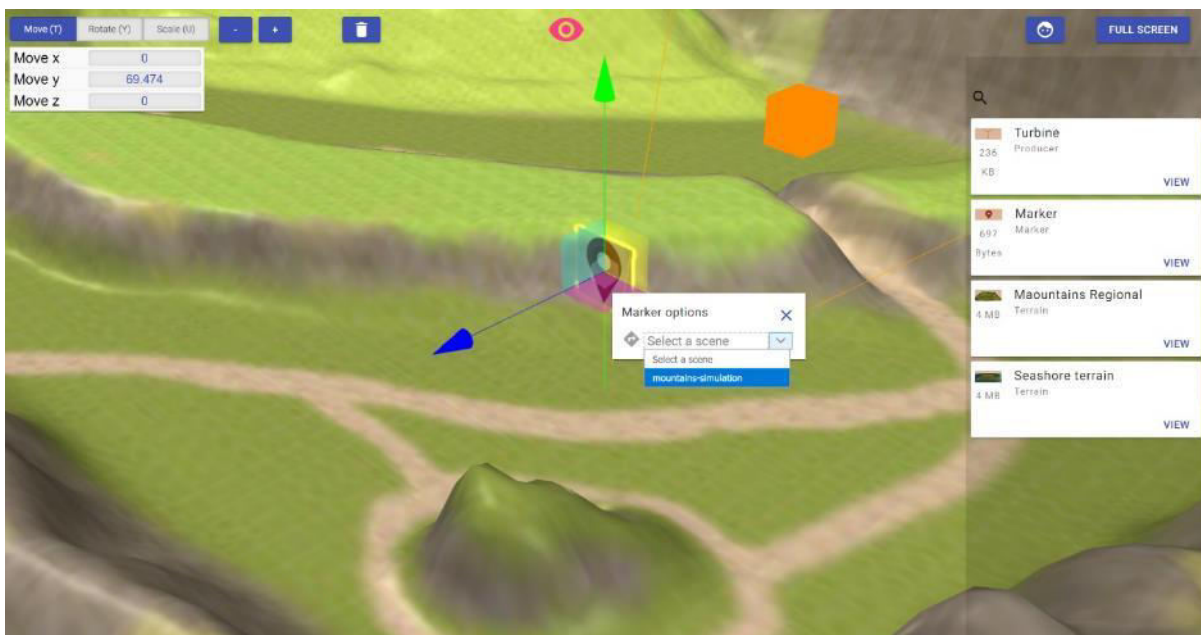


Figure 4.9: Editing a Regional scene.

### Step 6: Observe Analytics

Analytics can be viewed using the tabs in the blue ribbon of the Scene Editor. In the “Analytics” tab, the deep analytics can be viewed. The “At-Risk-Student” shows shallow analytics such as the session statistics.

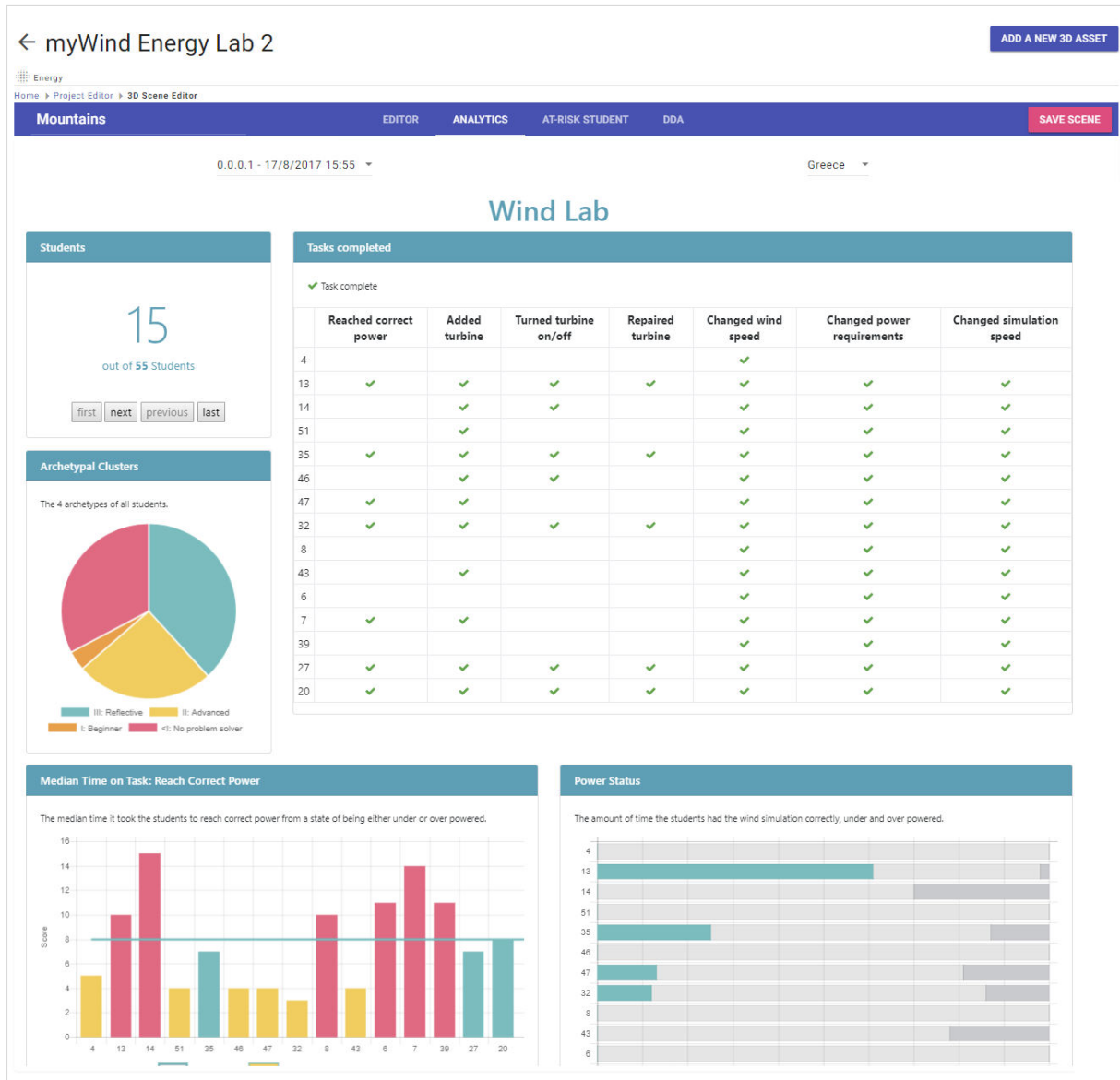


Figure 4.10: Observation of game analytics for the Wind Energy lab.

The “DDA” allows to make and observe strategies for the Wind Energy Lab. The strategies include which Regional Scenes to load in the lab out of the whole set of Regional scenes, i.e. Mountain, Fields, Seashore scenes. An example is shown in Figure 4.11. Each strategy is a list of scenes. S1 contains Mountains and Seashore. S2 contains Mountains and Fields scenes. S3 contains Seashore and Fields scenes. Each strategy is deployed to the 1/3 of the total learners.

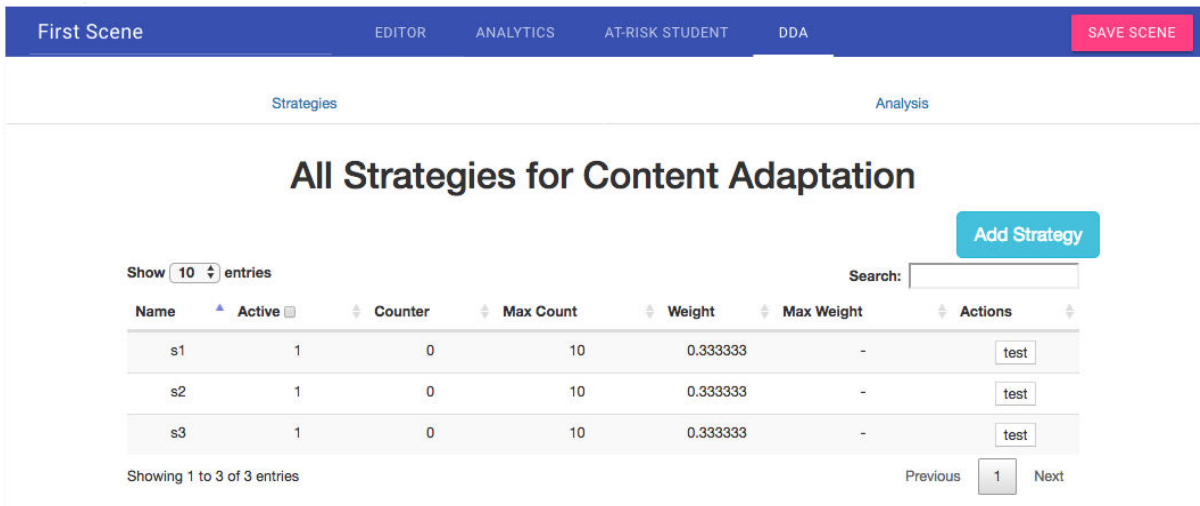


Figure 4.11: Strategies overview for the Wind Energy lab.

### Step 8: Compile and Disseminate

The lab project can be compiled in the Project Editor by pressing “Compile Lab” as shown in Figure 4.12. The lab can be compiled to one of the platforms that can be selected using the Platform widget, i.e. Windows, Mac, Linux and Web.

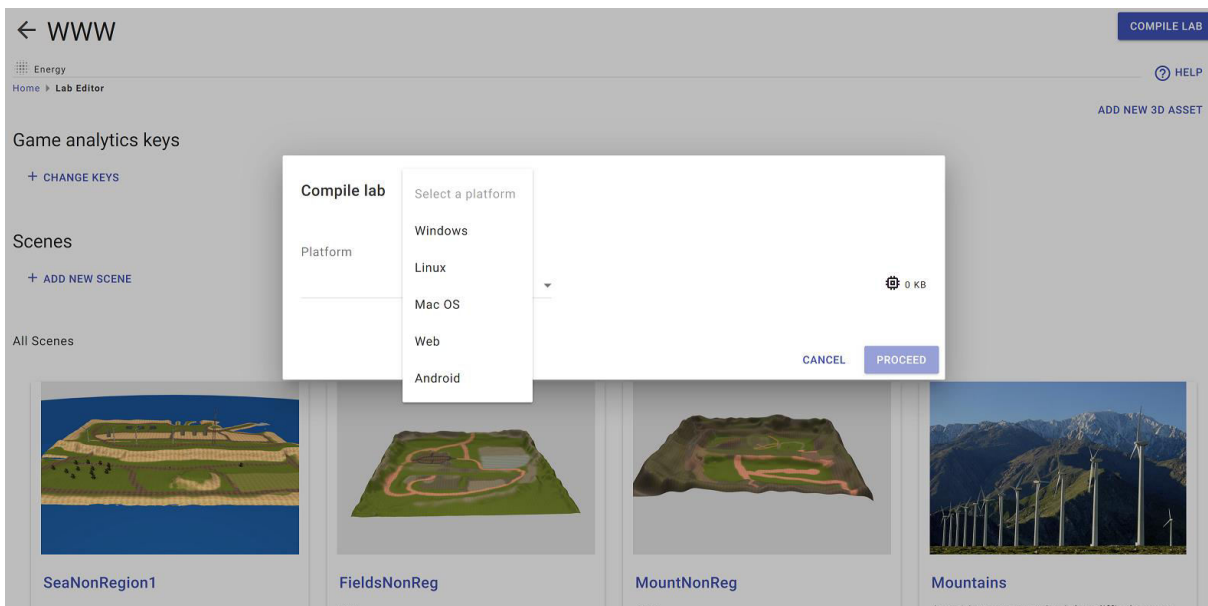


Figure 4.12: Selecting the platform for compiling the Wind Energy lab.

After pressing Proceed, the compiling process is initiated and a progress bar is shown as in the left part of Figure 4.12. The resulted lab can be accessed as shown in the right part of the figure. The lab can be either downloaded or be played with a web link if it is compiled for Web format.



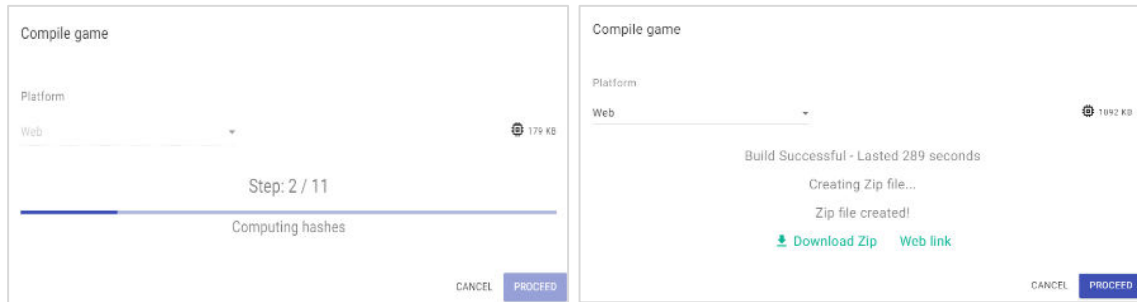


Figure 4.13: Compiling process monitoring and result.

## 4.2 Lab playing

### Step 1: Open the lab

The generated lab is provided through a web link. A precompiled version can be found in

[https://envisagelabs.iti.gr/games/Energy\\_V2/](https://envisagelabs.iti.gr/games/Energy_V2/)

### Step 2: How to start playing

When the browser has loaded the lab, the player is transferred to the main menu scene, where she/he can read information about the tasks he must complete as well as the controls used throughout the lab. After pressing the play button, the input scene is loaded asking for login information in Figure 4.14.



Figure 4.14: Main menu screen on the left and the login screen on the right.

### Step 3: Regional scenes selection

After the player has filled in all the input fields, the player is transferred to the first stage of the wind farm construction, where he/she can choose from a list of three available regions to install the wind farm, as shown in Figure 4.15. Every area holds different characteristics that can have an impact in the performance of the farm. To choose a regional area the player must click on one of the green buttons in the bottom of the screen. Also, in case changes need to be made to the login information, the player can return back by clicking the exit button (top left corner).





Figure 4.15: The three available main areas in the Regional selection scene.

#### Step 4: Subarea selection scene

After the player has picked a region, a new scene is loaded where the player can locate a number of markers throughout the scene terrain. This scene is the subarea selection and gives a 3D representation of the region that has been chosen by the player. Here, by using the WASD keys or by moving the mouse, the learner can fly through the scene in different directions. The purpose is to choose one of the available markers by hovering the mouse cursor above them. If the marker’s displayed characteristics satisfy the player, then the last can pick that subarea (marker) to install his farm by a left mouse click action in Figure 4.16.



Figure 4.16: The subarea selection scene (Mountains regions).

**Step 5: Turbine Selection**

Subsequently, the player is transferred to the turbine selection process where a choice concerning the turbine for the farm is made, as shown in Figure 4.17. Again the selection is very easy to make by just clicking on the dropdown screen element. To aid the player’s choice a table with different turbine types and their characteristics is displayed.

**Turbine selection**

Depending on the average wind speed prevailing in the area, different wind turbines are used. Select a wind turbine type to use in your wind farm by looking on the detailed table below.

Wind class I

▼

✓ Turbine A  
Turbine B  
Turbine C

Wind class I (10m/s)	Type of wind turbine	Power	Rotor diameter	Cost
	A	6MW	128m	5\$
	B	3MW	90m	3\$
	C	900KW	52m	1\$

Wind class II (8,5m/s)	Type of wind turbine	Power	Rotor diameter	Cost
	D	3MW	90m	3\$
	E	2MW	90m	2\$
	F	850KW	60m	1\$

Wind class III (7,5m/s)	Type of wind turbine	Power	Rotor diameter	Cost
	G	3MW	126m	4\$
	H	2MW	90m	2\$
	I	850KW	60m	1\$

Figure 4.17: The turbine selection scene.

**Step 6: Simulation scene**

After the player has made all the required actions to install and setup the wind farm, the simulation scene follows. Here, the player can control the wind turbines for producing the appropriate amount of energy, based on the speed of the wind. Like in previous scenes the player can move using either the mouse or the WASD keys and interact with the turbines (turn on/off) by hovering the mouse cursor over them. The simulation runs for 3 minutes and the player can get real-time glimpse of the usage values (bottom left corner) such as the wind farm usage, produced electricity, wind speed and the energy requirements. In case the user wants to exit the simulation, he can do so by clicking the menu button (yellow button top left corner) and see all the available options (Figure 4.18).



Figure 4.18: Wind Energy simulation scene.

### Step 7: Gamification elements

Wind energy lab is an educational lab and measure of performance could not be left out of the design. After the player finishes the simulation a multiple choice quiz is presented, which asks general questions regarding future actions that could be taken for the player’s wind farm. Moreover, throughout the lab and the quiz, the options that the player chooses are validated resulting in an overall score in the end of the lab. Last but not least, an analysis of the wind farm usage, cost and general actions are presented to the player when the simulation has finished. In the end the player can exit the lab or play again to increase the total score as shown in Figure 4.19.

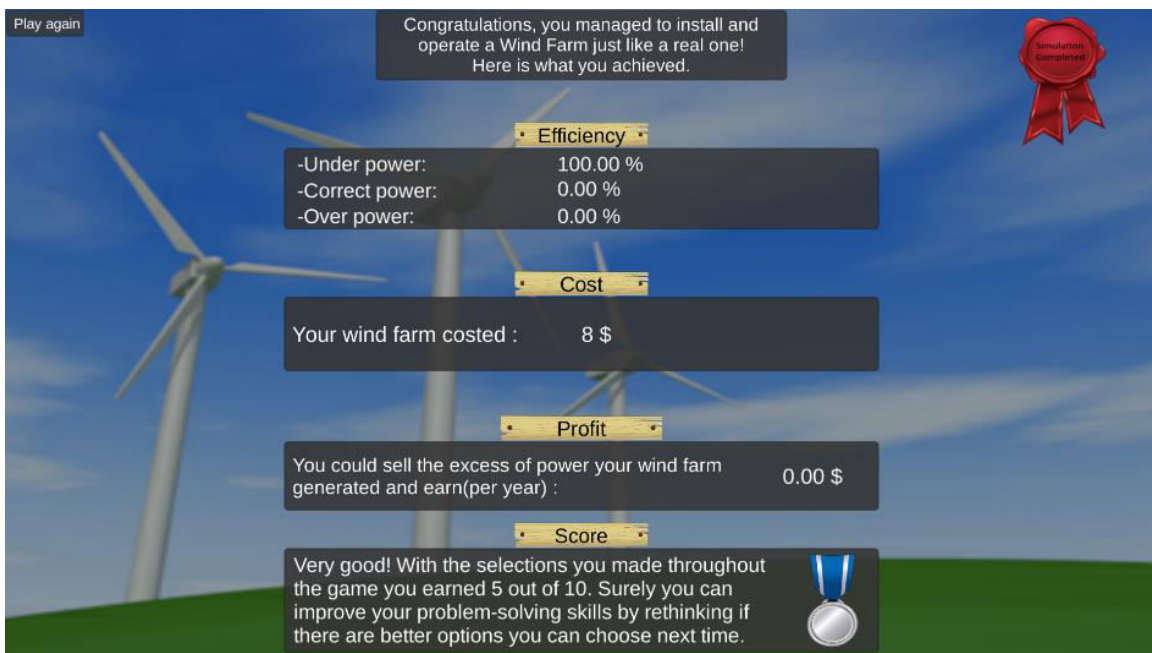


Figure 4.19: The final scene of the lab displaying the total score gathered.

## 5. Summary and future developments

The final version of the virtual labs authoring tool is a complete solution for educators that allows them to author Wind Energy and Chemistry labs. Significant improvements were made towards reducing the amount of time required to author a lab from 1 hour into 15 minutes by having shared assets from certain predefined labs. The distinction between web server (Linux with Apache server) and lab compiling server (Windows with Unity3D) allows to lower significantly web pages response times and thus make the platform more appealing. The game analytics mechanism allows to embody analytics by default in each lab and thus have a feedback mechanism per lab. The strategy making mechanism works as a content adaptation mechanism and allows making content changes in the lab without re-deploying it. In the remaining months of the project, the aforementioned features will be fully tested and debugged to ensure high quality and robustness. The compiling into Android platform will be also considered. In the future, the platform can be expanded to include more lab features such as molecule reactions and physical properties of molecules as well as other sources of energy for the Wind energy lab, but also incorporate improvements from an audio-visual perspective.

Overall, the architecture of the authoring tool is designed in a bottom-up approach in order to be expanded in the future with more features. The design followed is a generic one where each entity such as game, scene, asset, and 3D model is well defined in a structured form. Taxonomies and class inheritance logic allows to hide all trivial details from educators that are not familiarized with the terminology of game technologies. We believe that in the future ENVISAGE software will find track on virtual labs authoring projects, and game projects in general, due to its simplicity and innovative approach.

## 6. References

- [1] ENVISAGE Consortium, “D2.4 Updated shallow analytics and visualization strategies”, February 2018
- [2] ENVISAGE Consortium, “D3.2 – Updated predictive analytics and course adaptation methods”, February 2018
- [3] ENVISAGE Consortium, “D4.2 – First version of the virtual labs authoring tool”, July 2017
- [4] ENVISAGE Consortium, “D5.2 – Implementation of the educational scenarios and evaluation report (first phase) ”, September 2017