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Supporting the Assessment of Problem Solving Competences through Inquiry-based Teaching in School Science Education: The Inspiring Science Education Tools

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The Inspiring Science project has received funding from the European Union's ICT Policy Support Programme as part of the Competitiveness and Innovation Framework Programme. This publication reflects only the author's views and the European Union is not liable for any use that might be made of information contained therein.

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    - The need for inquiry based approaches
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Presentation Outline (2/3)

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Part A: School Science Education and Inquiry-based Learning

School Science Education: Why is it important?

- **Science[1] education** plays a critical role in societies' competitiveness and economic future.
- Science education is essential for students of all backgrounds, talents, interests, and abilities. Understanding how Science is part of our daily lives can give students a great foundation for success in life.
- All students need to cultivate competences that develop their **scientific literacy**, namely: "*the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen*" (OECD, 2015)
- As a result, Science Education is recognized as a **top priority for school education** worldwide, and, thus, a key challenge for technology-supported and technology-enabled school education innovations (Johnson et. al., 2012)

Johnson, L., Adams, S., Cummins, M., and Estrada, V. (2012). Technology Outlook for STEM+ Education 2012-2017: An NMC Horizon Report Sector Analysis. Austin, Texas: The New Media Consortium.

OECD. (2013). PISA 2015 draft science framework

[1]Hereafter, when referring to Science at large, we mean natural Sciences (physics, biology, chemistry, astronomy, geology etc) technology (including computer science) and mathematics also referred to as STEM (Science, Technology, Engineering and Mathematics)

School Science Education: The need for inquiry based approaches

- Developing **scientific literacy** in compulsory school education requires preparing students in four main strands, namely (Alberts, 2009):
  - To know, use, and interpret scientific explanations of the natural world
  - To generate and evaluate scientific evidence and explanations
  - To understand the nature and development of scientific knowledge
  - To participate productively in scientific practices and discourse
- Thus, there is a clear need for **inquiry based approaches** towards developing students' scientific literacy
- **Inquiry** is the process in which students are engaged in scientifically oriented questions, perform active experimentation, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations (National Research Council, 2000)

Alberts, B. (2009). Redefining science education. Science, 323(5913), 437.

National Research Council. (2000). Inquiry and the national science education standards. A guide for teaching and learning. Washington DC: National Academy Press

Inquiry-based Learning: Overview

- Several studies have demonstrated that **Inquiry-based Learning**:
  - leads to better acquisition of ***domain*** (conceptual) ***knowledge*** (Hwang et al., 2013)
  - has a significant positive influence on students' ***motivation*** (Tuan et al. 2005)
  - leads to increased students' ***engagement*** (Tsai et al., 2006)
  - has a significant positive influence on students' ***attitudes towards science*** (Koksal & Berberoglu, 2014)

Hwang, G. J., Wu, P. H., Zhuang, Y. Y., & Huang, Y. M. (2013). Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students. Interactive Learning Environments, 21(4), 338-354.

Koksal, E. A., & Berberoglu, G. (2014). The Effect of Guided-Inquiry Instruction on 6th Grade Turkish Students' Achievement, Science Process Skills, and Attitudes Toward Science. *International Journal of Science Education*, *36*(1), 66-78.

Tsai, C. C., & Tuan, H. L. (2006). Investigating the inquiry-based instruction effects on the 8th graders' perceptions about learning environments in the physical science. In *Hongkong: APERA Conference*.

Tuan, H.L., Chin, C.C., Tsai, C.C., & Cheng, S.F. (2005). Investigating the effectiveness of inquiry instruction of different learning styles students. *International Journal of Science and Mathematics Education, 3,* 541-566.

Inquiry-based Learning: Main Phases (1/2)

- Inquiry-based learning is often organized into inquiry phases that together form an **inquiry cycle**. However, different variations on what is called the inquiry cycle can be found throughout the literature (Pedaste et al., 2015)
- A widely used inquiry learning model is the **5E Model**, which lists five inquiry phases: **E**ngagement, **E**xploration, **E**xplanation, **E**laboration, and **E**valuation (Bybee et al., 2006).

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. T., Manoli, C., Zacharia, Z. & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational Research Review, 14, 47-61.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. Colorado Springs, CO: BSCS.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. International Journal of Science Education, 32(3), 349-377.

Inquiry-based Learning: Main Phases (2/2)

- In our work, we have adapted the 5E Model by considering also the inquiry cycle proposed by Bell et al. (2010). More specifically, the following inquiry phases has been adopted:
  - **Orienting & Asking Questions:** This phase involves the presentation of the problem to be engaged with and aims to provoke curiosity.
  - **Hypothesis Generation & Design:** The second phase involves the formulation of initial hypotheses from the students based on their own reason and current understanding of the matter at hand.
  - **Planning & Investigation:** The third phase is related to the collection, analysis and organization of the research/experimentation processes and the related tools/resources that will facilitate these. This can be discovered by the students or provided by the teacher.
  - **Analysis & Interpretation:** During the fourth phase, the learners engage in experimentations following the processes outlined in Phase 3 and utilizing the tools/resources selected in the same Phase.
  - **Conclusion & Evaluation:** The fifth phase includes reflective analysis of the learners initial hypotheses based on the newly acquired knowledge and experience. Moreover, it aims to assist learners in gaining a more holistic view of the problem

Inquiry-based Learning: Cultivation of Problem Solving Competence

- Several studies have also provided evidence that **Inquiry-based Learning** (Raes et al., 2012; Prince & Felder, 2006):
  - promotes self-regulated learning and meta-cognition
  - develops the cognitive process that cultivates ***problem solving (PS) competence***
- Thus, to be able to measure (among others) the **effectiveness** of inquiry-based learning, assessment of students' problem-solving competences is needed

Raes, A., Schellens, T., De Wever, B., & Vanderhoven, E. (2012). Scaffolding information problem solving in web-based collaborative inquiry learning. Computers & Education, 59(1), 82-94.

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of Engineering Education, 95(2), 123-138

Problem Solving Competence: Why is it important?

- **Problem solving competence** is a central objective for most compulsory education (K12) curricula and a critical competence for both professional career readiness and effective citizenship (Greiff et al., 2014).
- Problem solving competence is*: "an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen"* (OECD, 2013)
- The acquisition of high levels of problem solving competence provides students the capacity to think critically and creatively in solving complex real-life problems (Lesh & Zawojewski, 2007)
- Yet, both developing and ***assessing*** problem solving competence as part of School Education remains an open challenge

Greiff, S., Wüstenberg, S., Csapó, B., Demetriou, A., Hautamäki, J., Graesser, A. C., & Martin, R. (2014). Domain-general problem solving skills and education in the 21st century. Educational Research Review, 13, 74-83.

Lesh, R. and J.S. Zawojewski (2007), "Problem solving and modeling", in F. Lester (ed.), The Handbook of Research on Mathematics Teaching and Learning (2nd ed.), National Council of Teachers of Mathematics, Reston, Virginia, and Information Age Publishing, Charlotte, North Carolina (joint publication), pp. 763-804.

Organization for Economic Co-operation and Development (OECD) (2013). PISA 2012 assessment and analytical framework: mathematics, reading, science, problem solving and financial literacy.

Assessing Problem Solving Competence: The PISA 2012 Problem Solving Framework (PSF) (1/3)

- A widely accepted framework for assessing individual students' problem solving competence at large scale is **PISA 2012 Problem Solving Framework (PSF),** which has been developed by the Organization for Economic Co-operation and Development (OECD) to address the need for cross-nationally comparable evidence for student performance on problem solving
- It defines four (4) different steps for solving a complex problem namely (OECD, 2013):
  1. **Exploring and understanding the problem:**
     - exploring the problem situation (observing, interacting, searching for information and limitations)
     - understanding the given information and the information discovered while interacting with the problem situation.
  2. **Representing and formulating the problem:**
     - select relevant information, mentally organize and integrate with relevant prior knowledge.
     - shifting between representations or formulating hypotheses by identifying the relevant factors

Organization for Economic Co-operation and Development (OECD) (2013). PISA 2012 assessment and analytical framework: mathematics, reading, science, problem solving and financial literacy.

Assessing Problem Solving Competence: The PISA 2012 Problem Solving Framework (PSF) (2/3)

3. Planning and executing the strategy for solving the problem

- clarifying the overall goal and setting sub-goals
- devising a plan or strategy to reach the goal state. After that, in the executing phase, the plan will be carried out.

4. Monitoring and reflecting the solution

- monitor the progress towards reaching the goal at each stage including checking intermediate and final results, detecting unexpected events
- reflect on solutions from different perspectives and critically evaluate assumptions and alternative solutions.

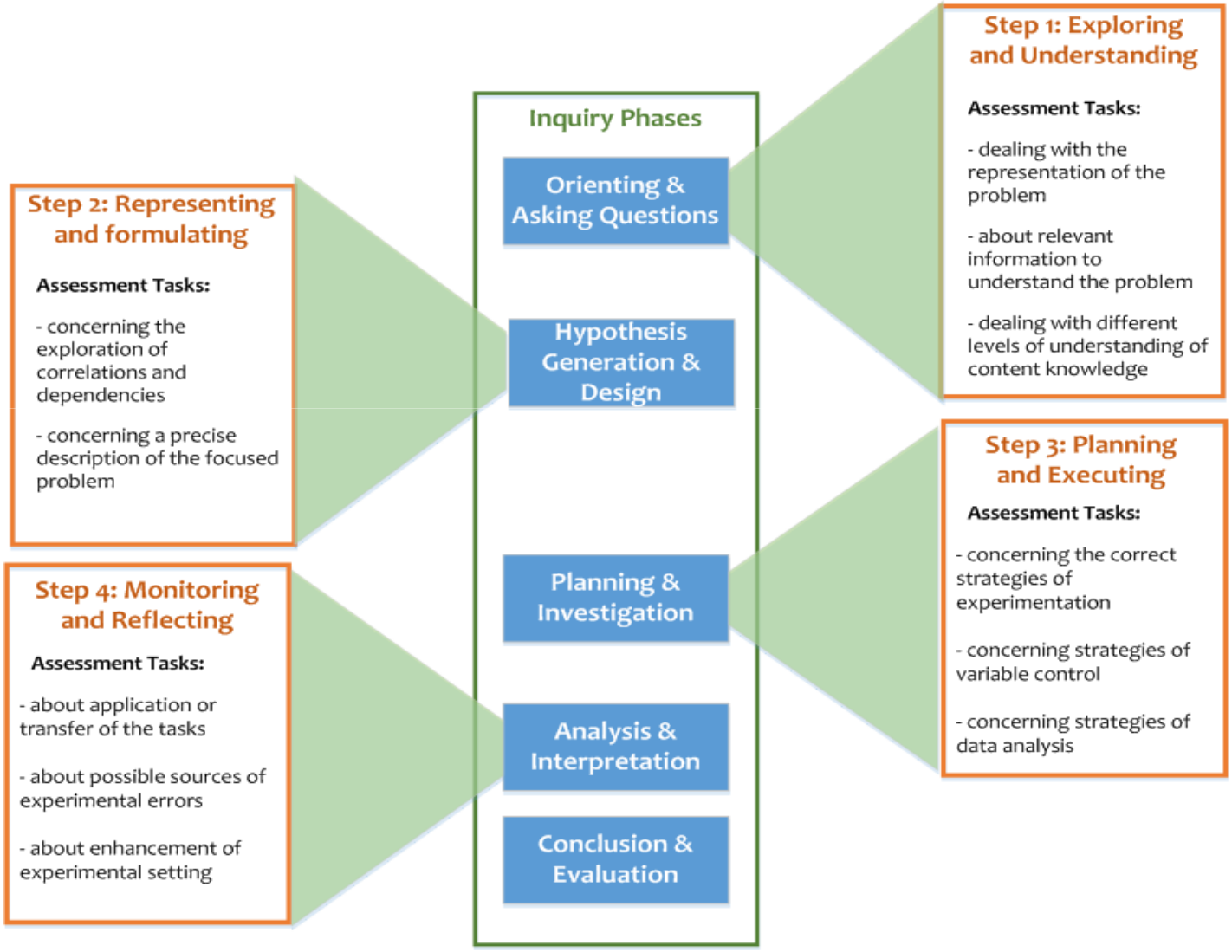
Assessing Problem Solving Competence: The PISA 2012 Problem Solving Framework (PSF) (3/3)

- The range of problem solving assessment tasks included in the PISA 2012 PSF allows for describing six levels of problem solving proficiency that can be grouped into three main categories, namely (OECD, 2014):
  - **High Performers (Level 6 and Level 5) -** students at this category can:
    - develop complete, coherent mental models of different situations
    - can find an answer through target exploration and a methodical execution of multi-step plans
  - **Moderate Performers (Level 4 and Level 3) -** students at this category can:
    - control moderately complex devices, but not always efficiently
    - handle multiple conditions or inter-related features by controlling the variables
  - **Low Performers (Level 2 and Level 1) -** student at this category can:
    - answer if a single, specific constrain has to be taken into account
    - partially describe the behavior of a simple, everyday topic.

OECD (2014). PISA 2012 Results: Creative Problem Solving: Students' Skills in Tackling Real-Life Problems (Volume V). PISA, OECD Publishing

Assessing Problem Solving Competence: Incorporating PISA 2012 PSF in Inquiry Cycle

- How the cognitive process of problem solving can be assessed in the different phases of the Inquiry Cycle??



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The Need for Tools to Support the Assessment of Problem Solving Competences through Inquiry-based Learning

- PISA 2012 problem solving competence assessment is **summative** (one-off assessment) and ***disconnected from the school practice***.
- There is lack of evidence to connect ***students' performance on problem solving competence*** to the ***specific design considerations*** of lesson plans and their teaching and learning activities.
- This shortcoming can hinder science ***teachers' capacity to reflect*** on and accordingly ***adapt their lesson plans*** towards enhancing students' performance on problem solving competence.

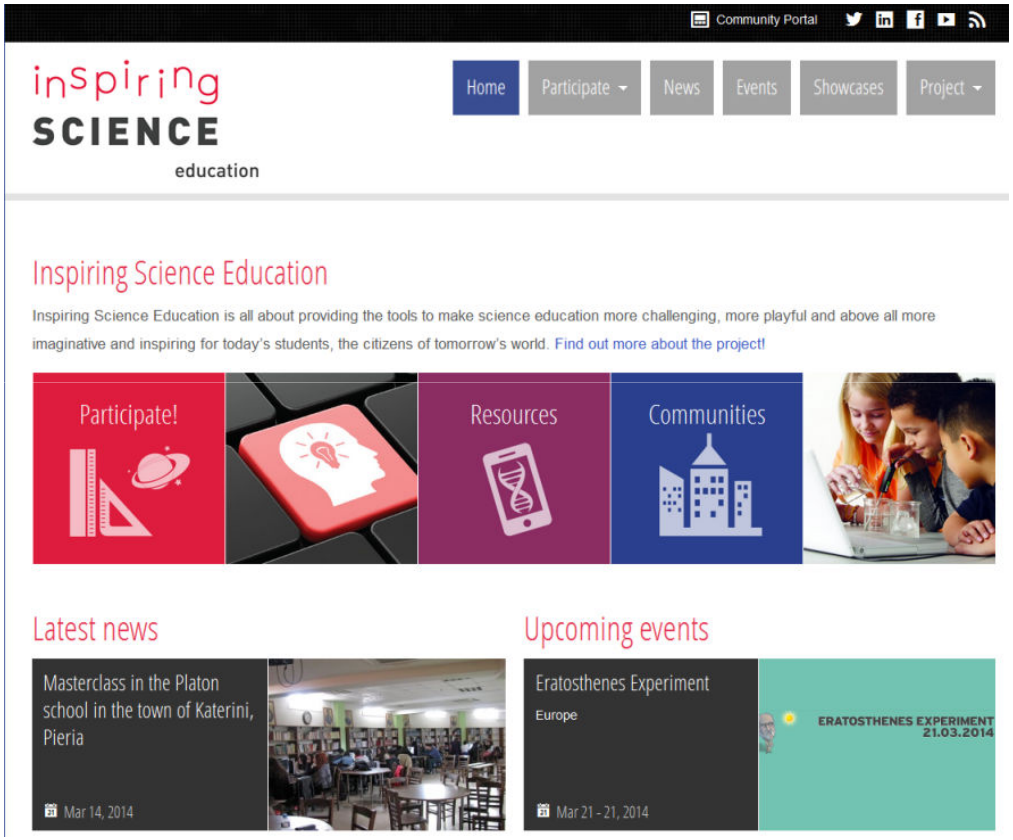
The Need for Tools to Support the Assessment of Problem Solving Competences through Inquiry-based Learning

- Thus, we need **tools** to support teachers to:
  - **Author** technology-enhanced science education lessons that follow the inquiry cycle (as proposed in slide #10) and by incorporating appropriate (PISA 2012 PSF compatible) assessment tasks (as proposed in slide #16)
  - **Deliver** technology-enhanced science education lessons with their students to ***collect assessment data*** (PISA 2012 PSF compatible) and monitor their students' problem solving competences, as well as reflect on and accordingly adapt their lesson plans for future delivery

Part B: The Inspiring Science Education Tools

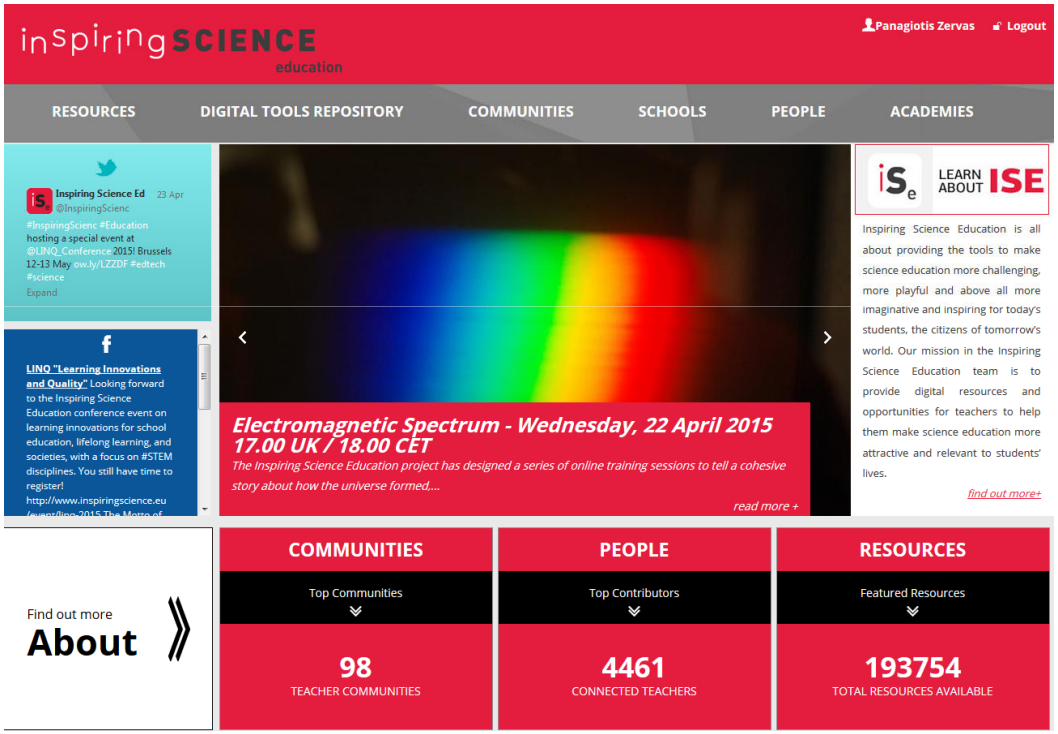
The Inspiring Science Education Project
http://www.inspiring-science.eu/

- Funded by European Commission's CIP-ICT Policy Support Programme
- 40 Months Project (started on 1/4/2013, ends on 31/7/2016)
- Expected to engage **5.000 schools**, **10.000 teachers** and **50.000 students**
- It has developed the technical infrastructure for designing and delivering technology enhanced science lessons:
  - following the inquiry cycle (as presented in slide #10)
  - incorporating the PISA 2012 PSF embedded in the various phases of the inquiry cycle (as presented in slide #16)



The ISE Portal: Overview

- The ISE Authoring and Delivery Tool have been developed and integrated to the ISE Portal (http://portal.opendiscoveryspace.eu/ise)
- A web-based infrastructure for European School Teachers for having access to:
  - a wide number of Digital Educational Resources from a federated network of repositories
  - a set of digital tools for science education from an appropriately designed repository of tools
  - Online teachers' communities and accompanying community tools such as forums, wikis and blogs
- Join here: http://portal.opendiscoveryspace.eu/ise



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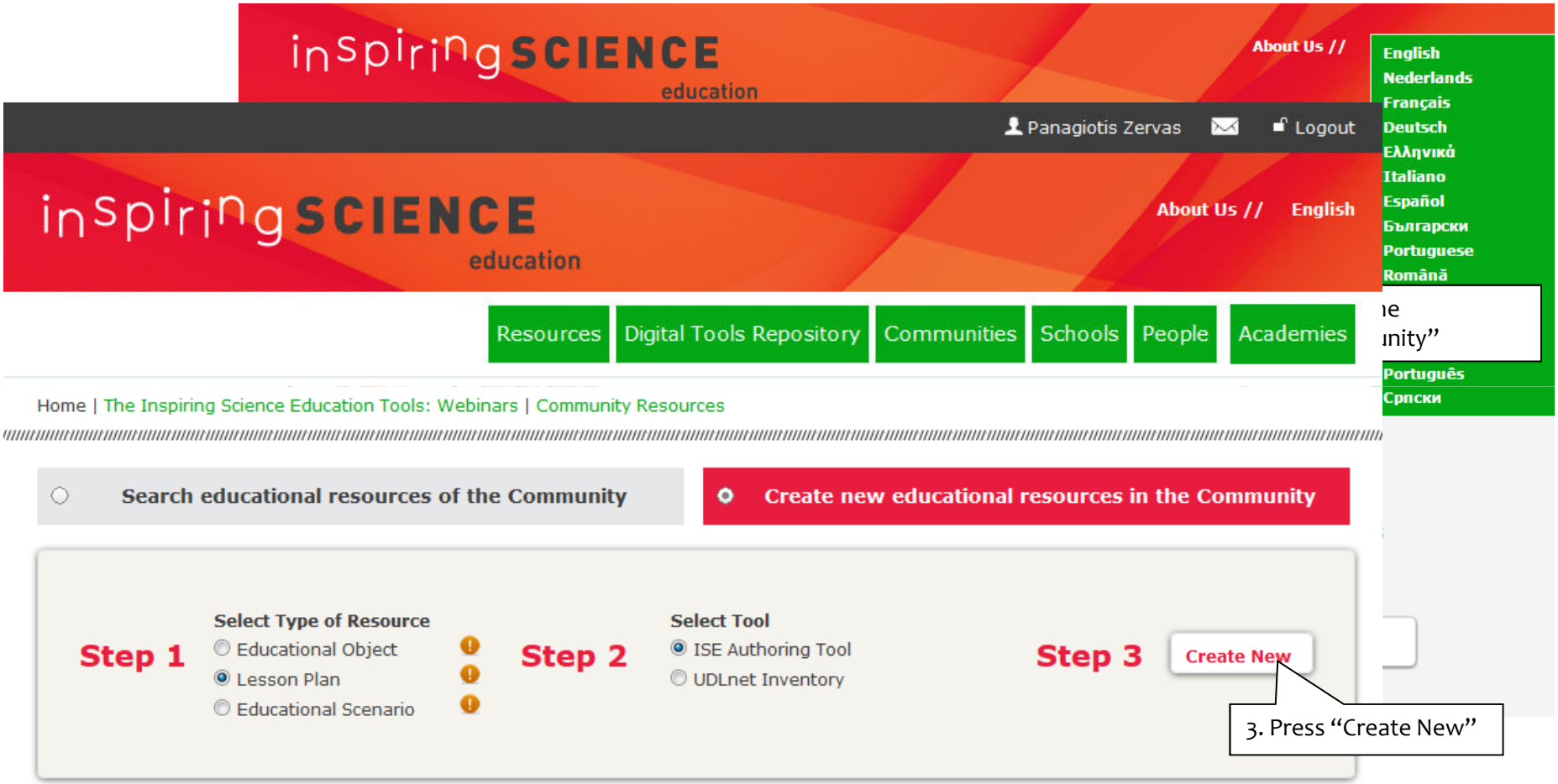
The ISE Portal: How to access the ISE Authoring Tool?



Community URL: http://portal.opendiscoveryspace.eu/community/inspiring-science-education-tools-webinars-829029

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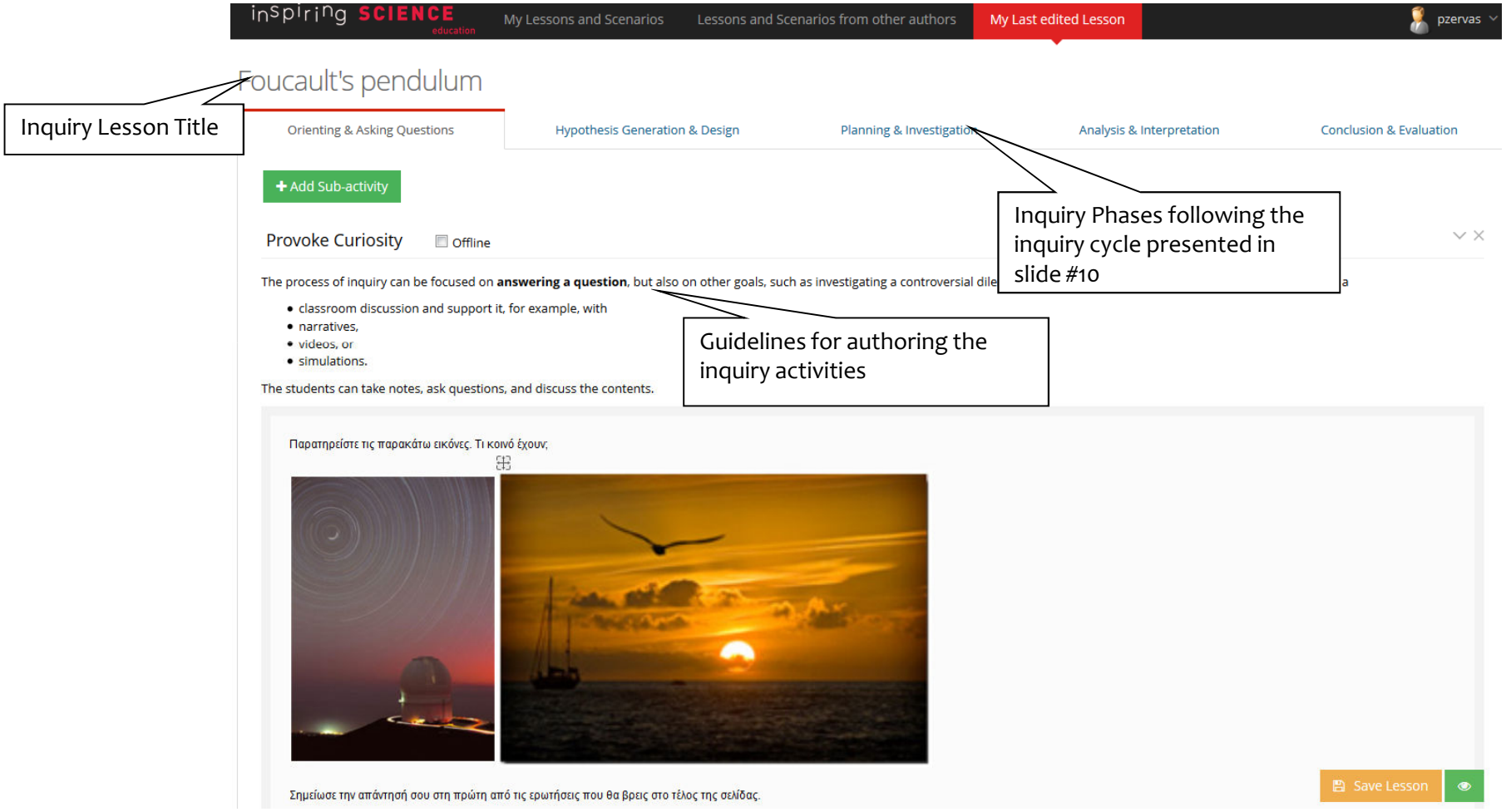
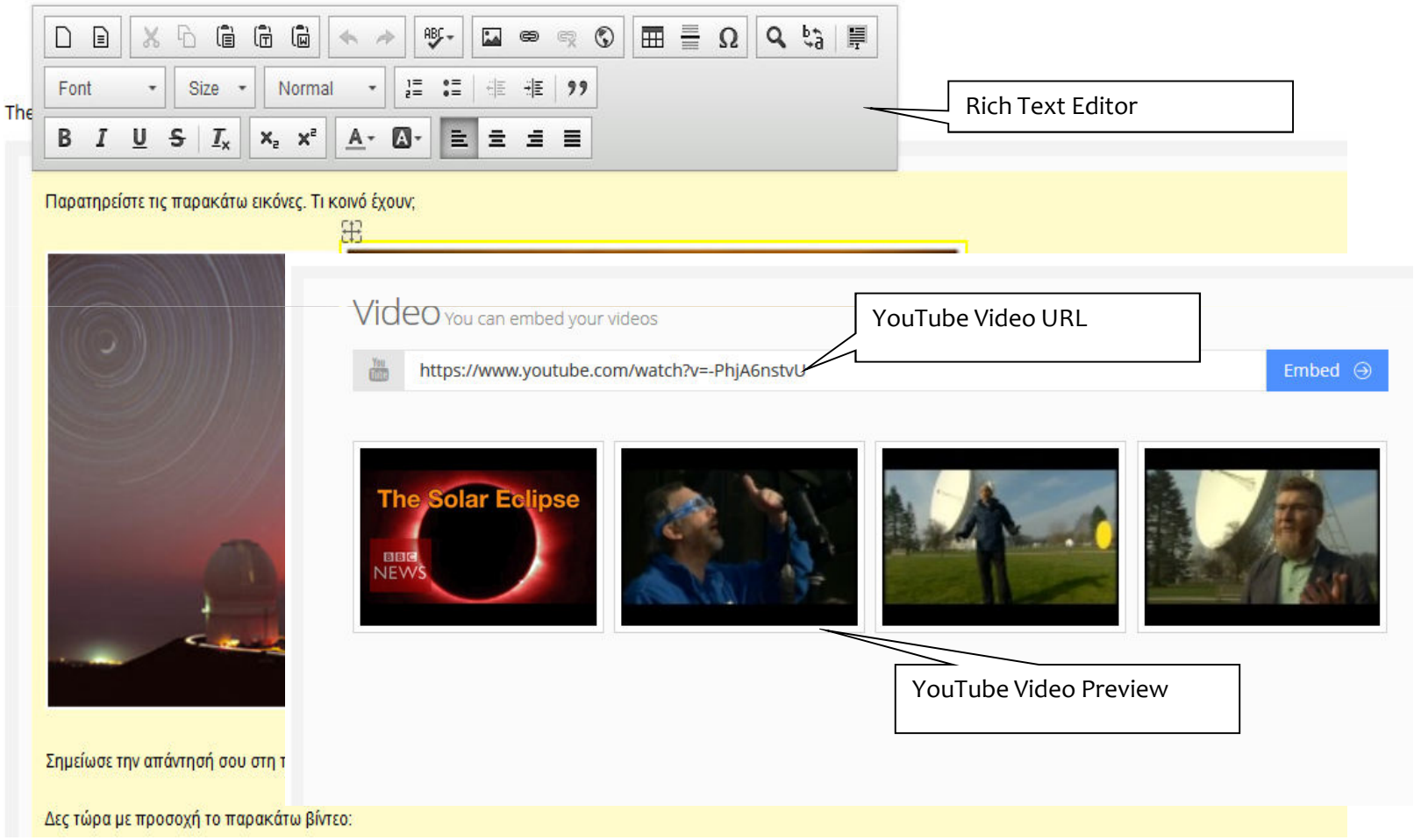
The ISE Authoring Tool: Design Considerations (A-DCs)

- **A-DC1:** Teachers should be able to develop technology-enhanced science education lessons following the inquiry cycle (as presented in slide #10).
- **A-DC2:** Each phase of the inquiry cycle includes a set of inquiry activities. Each inquiry activity should include:
  - **A-DC2.1:** Digital educational resources of any type (text, images, videos)
  - **A-DC2.2 :** External digital educational resources stored in the ISE Portal
  - **A-DC2.3:** External digital educational tools stored in the ISE Tools Repository
  - **A-DC2.4:** Guidelines/notes for the teacher to implement the inquiry activity
  - **A-DC2.5:** Assessment tasks to assess students' knowledge and provide feedback
- **A-DC3:** Teachers should be able to add at the end of each inquiry phase appropriately designed assessment tasks, so as the cognitive process of problem solving to be assessed (as presented in slide #16)
- **A-DC4:** Teachers should be able to store with educational metadata their technology-enhanced science education lessons to the ISE Portal, so as to be searchable from other teachers
- **A-DC5:** Teachers should be able to clone and adapt technology-enhanced science education lessons developed by other teachers. This means that teachers should be able to both copy an existing technology-enhanced science education lesson developed by another teacher (clone) and based on this, incorporate potential changes for addressing their needs (adapt)

The ISE Authoring Tool: Implementing A-DC1 - Develop an Inquiry lesson



The ISE Authoring Tool: Implementing A-DC2.1 - Develop an Inquiry Activity – Add Educational Resources



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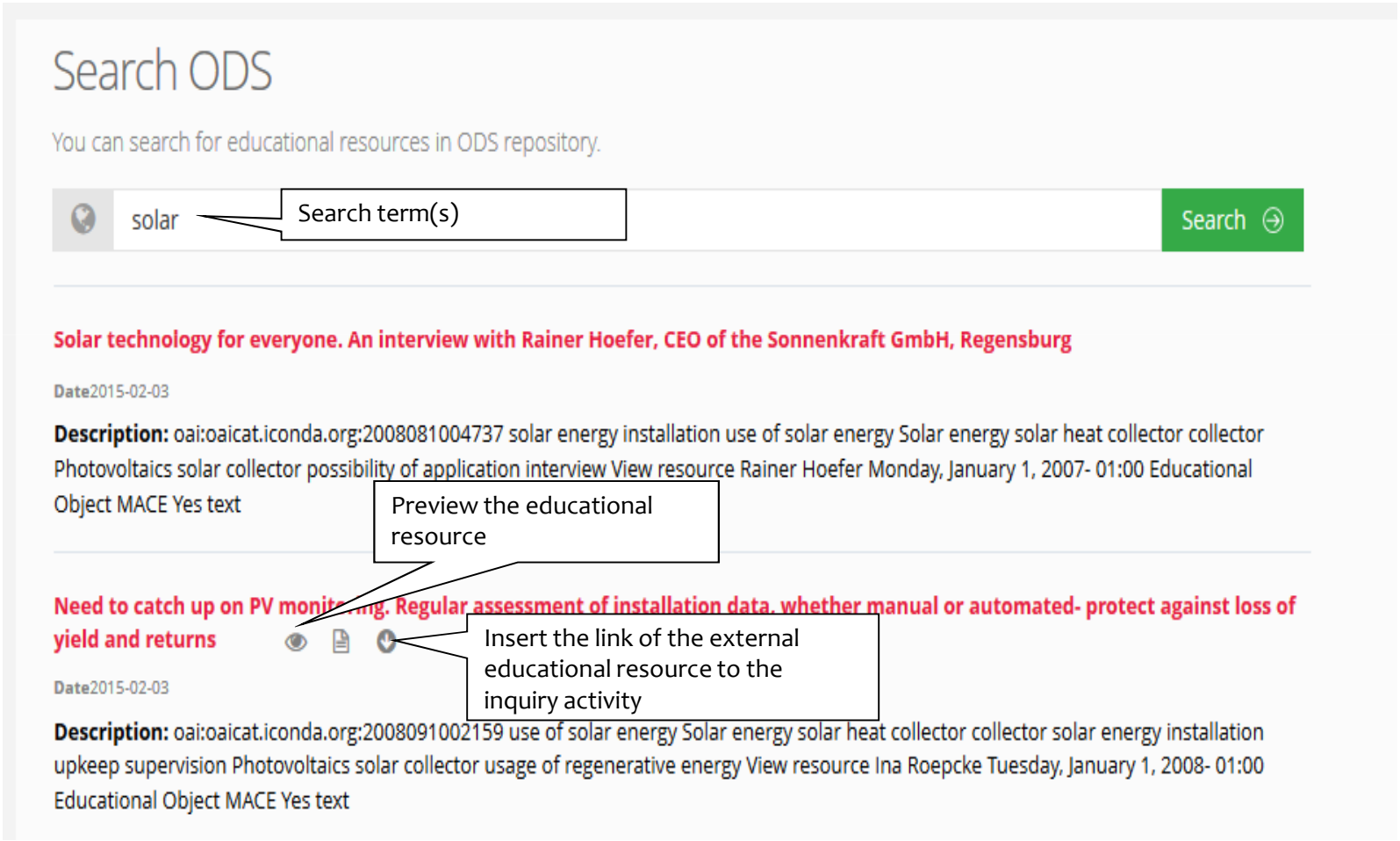
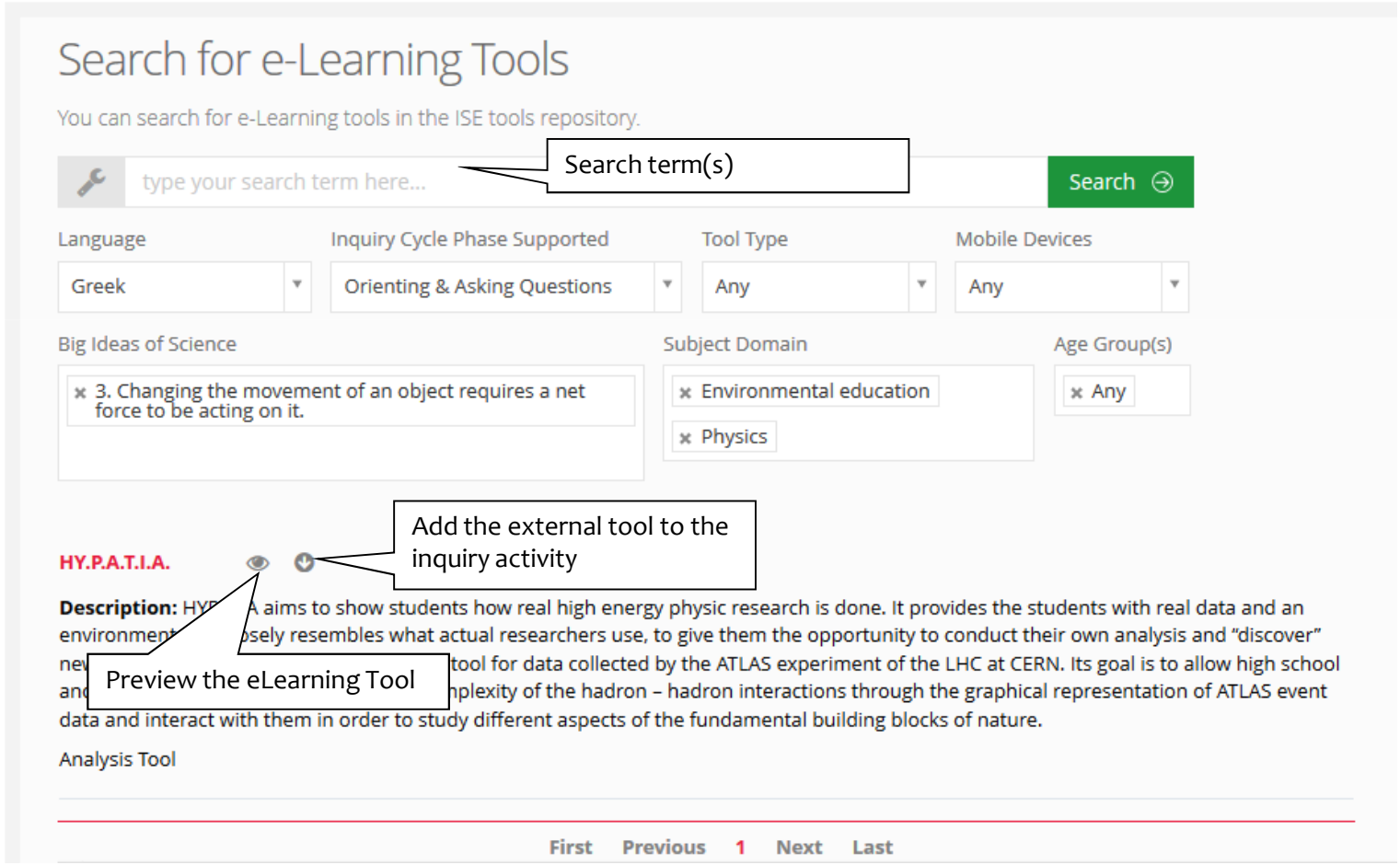
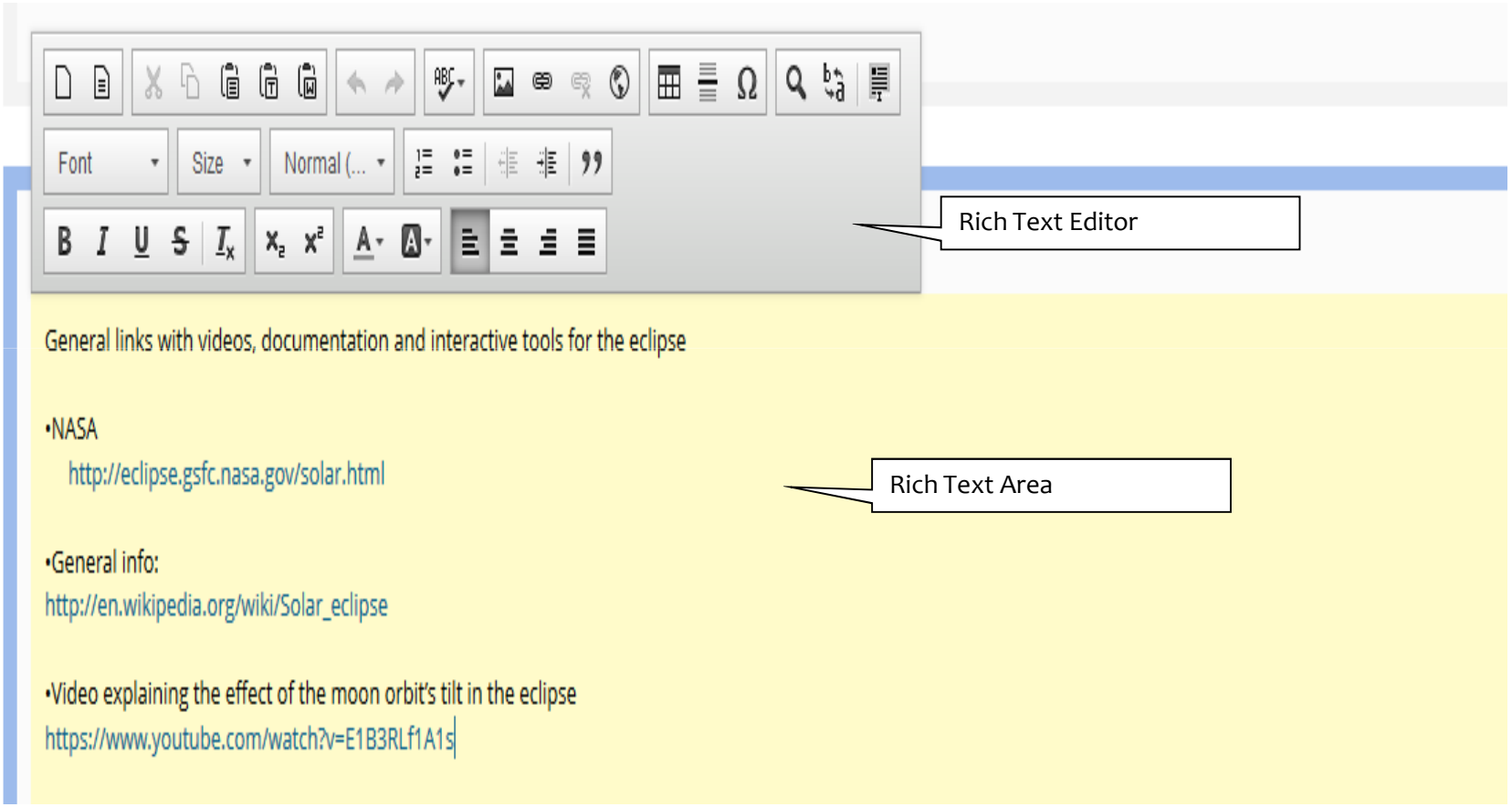
The ISE Authoring Tool: Implementing A-DC2.2 - Develop an Inquiry Activity – Add External Educational Resources



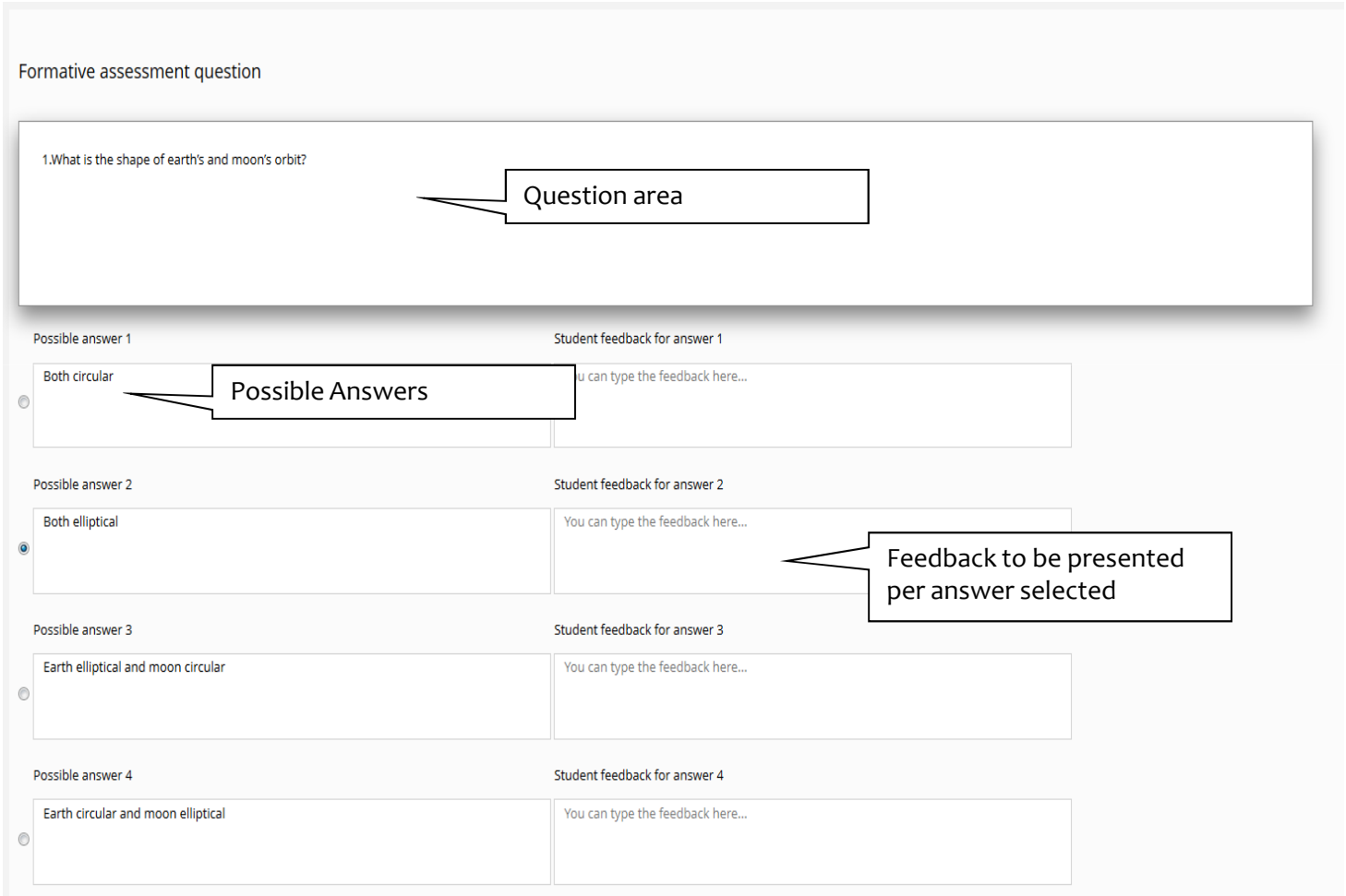
The ISE Authoring Tool: Implementing A-DC2.3 - Develop an Inquiry Activity – Add External Educational Tools



The ISE Authoring Tool: Implementing A-DC2.4 - Develop an Inquiry Activity – Add Teacher Notes/Guidelines

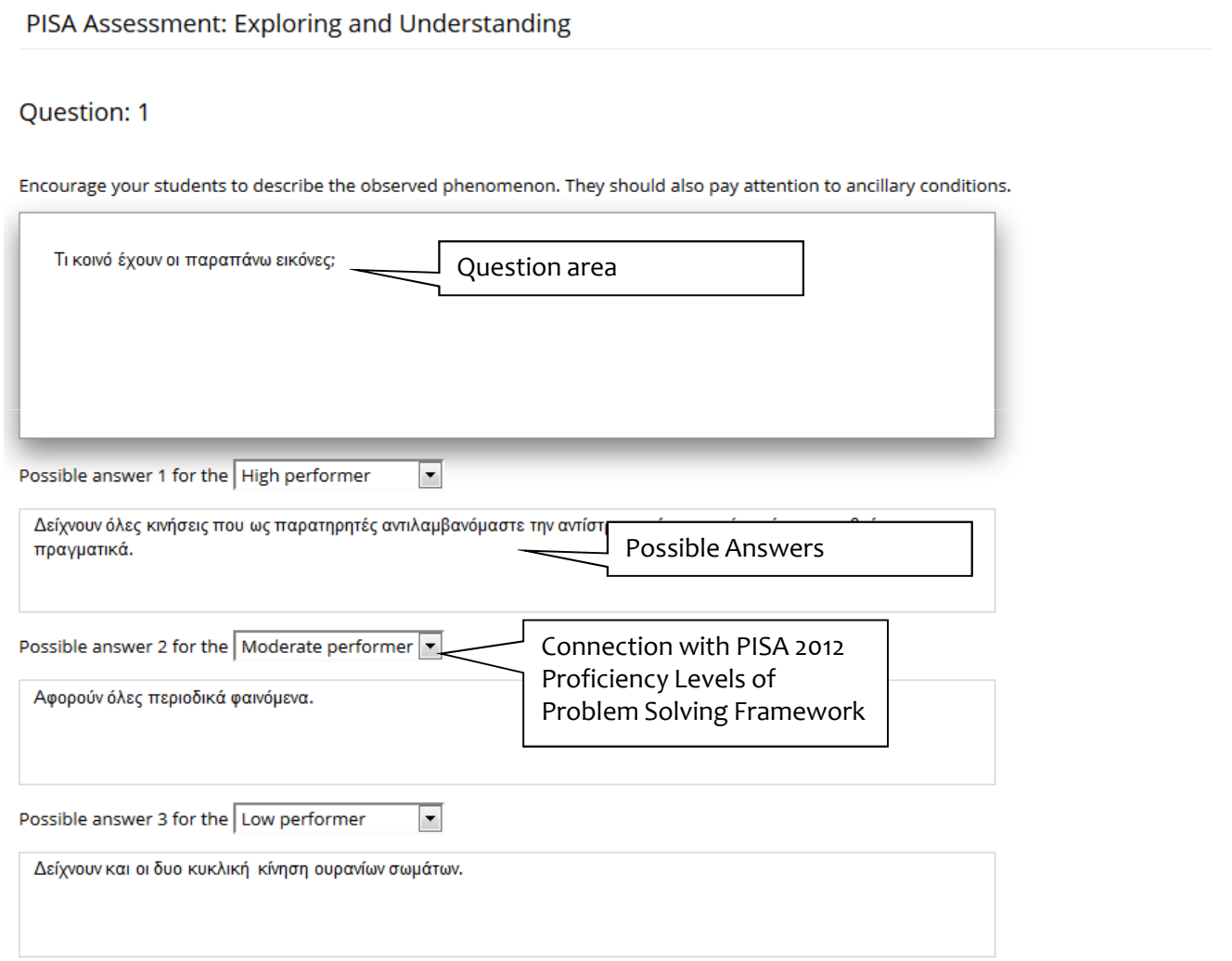


The ISE Authoring Tool: Implementing A-DC2.4 - Develop an Inquiry Activity – Add Knowledge Assessment Tasks



The ISE Authoring Tool: Implementing A-DC3 - Assess Problem Solving Process

- At the end of each inquiry phase, two questions are added to assess the problem solving process



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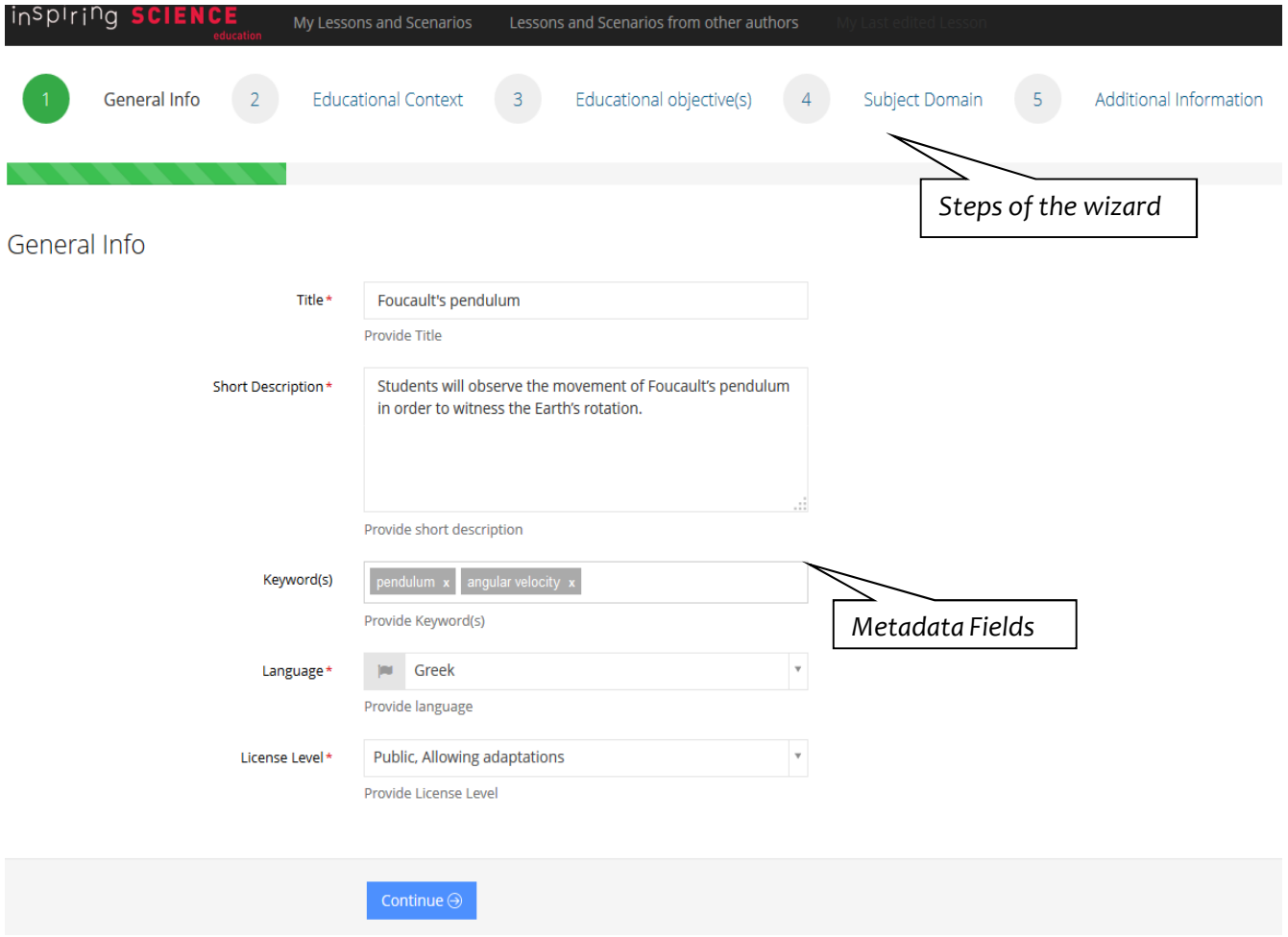
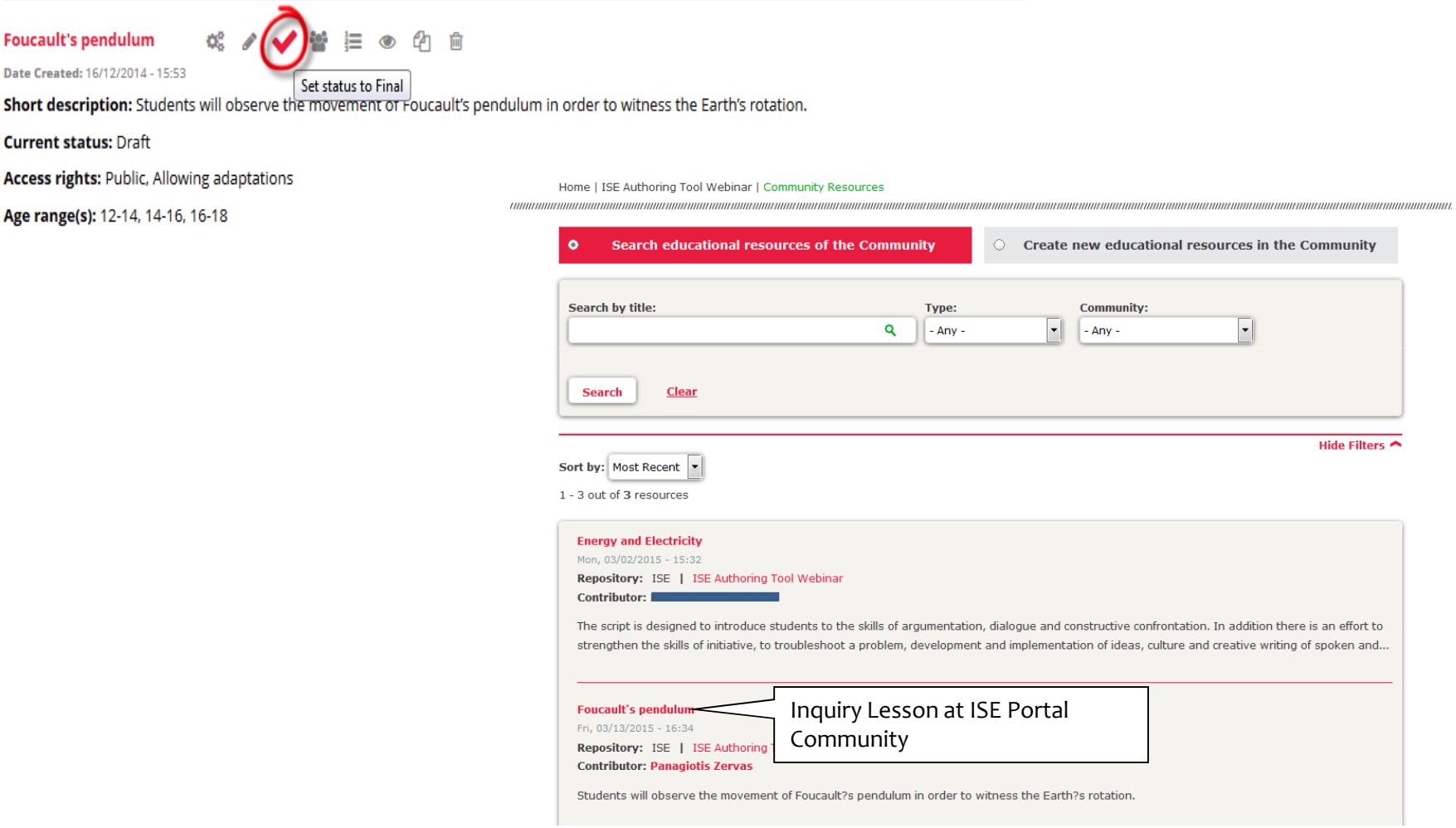
The ISE Authoring Tool: Implementing A-DC4 - Store Lesson to the ISE Portal – Add Metadata

- Step 1: General Info
- Step 2: Educational Context
- Step 3: Educational Objectives
- Step 4: Subject Domain
- Step 5: Additional Information



The ISE Authoring Tool: Implementing A-DC4 - Store Lesson to the ISE Portal – Publish Lesson



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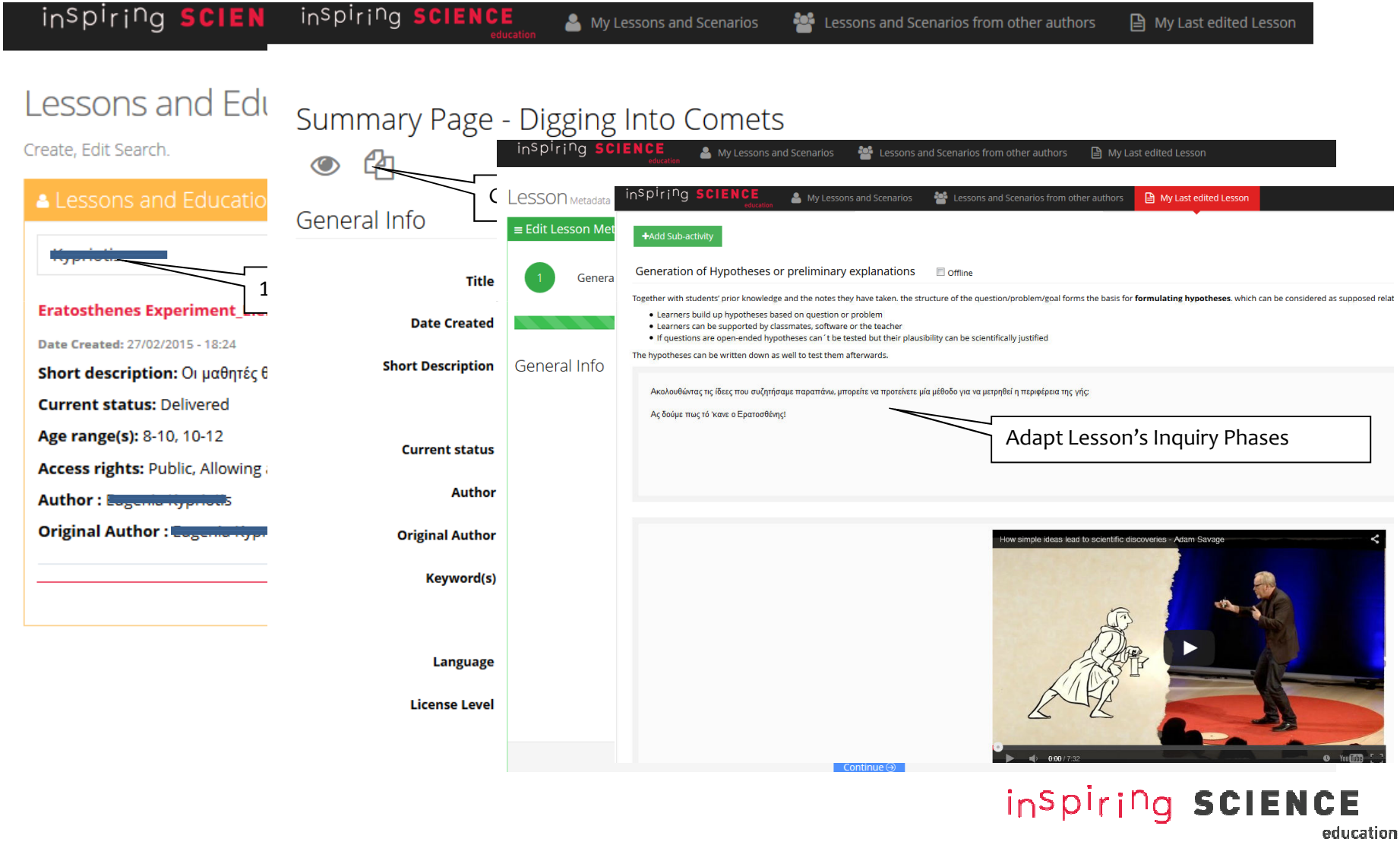
The ISE Authoring Tool: Implementing A-DC5 - Search Lessons from other Teachers – Clone and Adapt



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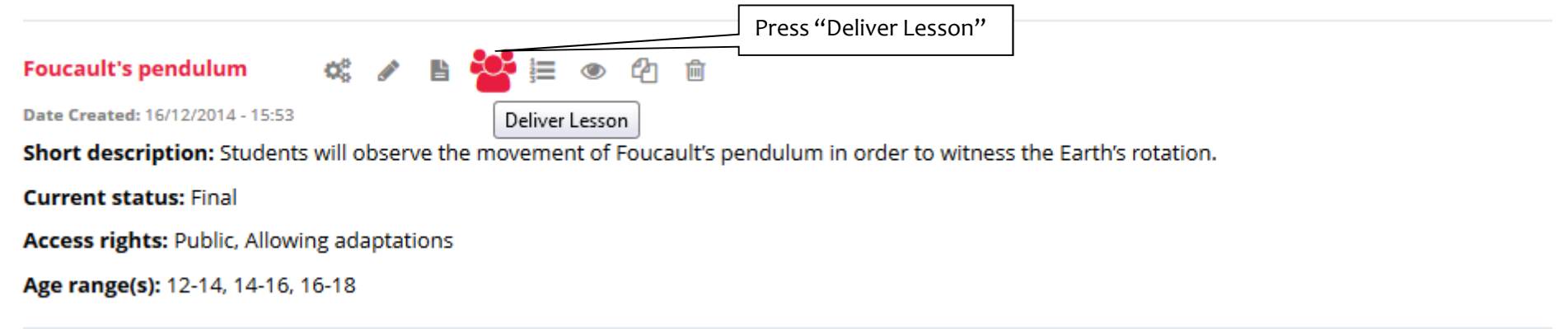
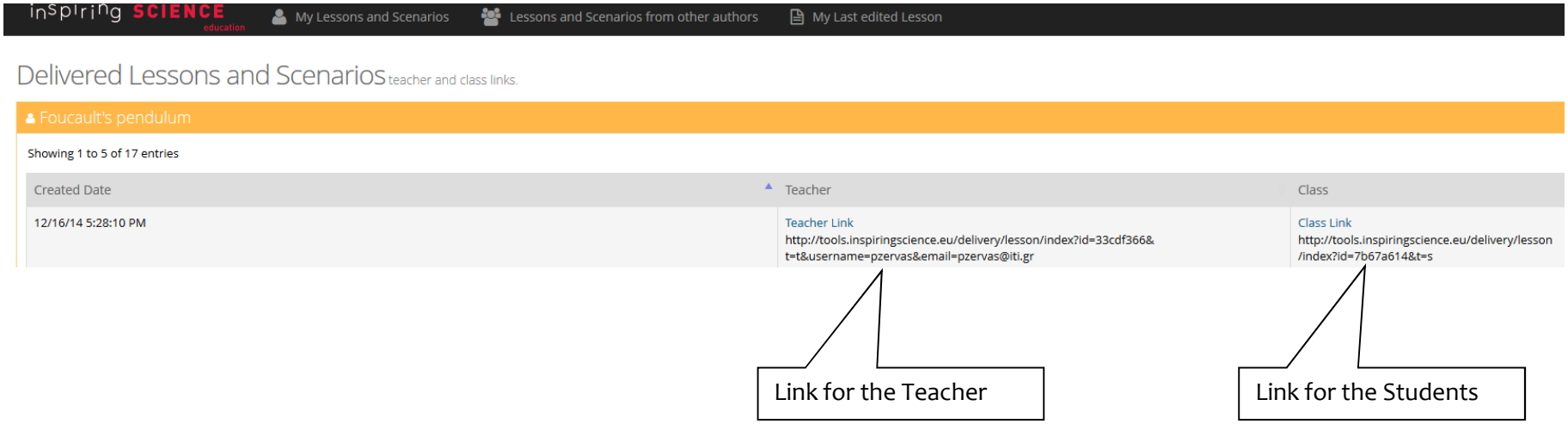
The ISE Delivery Tool: Design Considerations (D-DCs)

- **D-DC1:** Teachers and Students should be able to access the ISE Delivery Tool through unique web links produced by the ISE Authoring Tool for each lesson to be delivered
- **D-DC2:** Students should be able to enroll (considering data privacy issues) in science education lessons and execute the different phases in a fixed order, or "lockstep" fashion. The lockstep procedure means that students will not able to answer again the problem solving questions at the end of any inquiry phase when moved to the next one (OECD, 2013).
- **D-DC3:** Students should be to see at the end of the lesson, data about their performance, as well as how their performance is compared with the overall class performance.
- **D-DC4:** Teachers should be able to enroll in science education lessons along with their students and they should be able to see an augmented view of the lesson including: (a) notes/guidelines about how to execute specific inquiry activities and (b) the correct answers to problem solving and knowledge questions
- **D-DC5:** Teachers should be able to monitor (a) the students enrolled in their science education lessons (DC5.1), (b) students' performance on problem solving competence assessment (DC5.2), (c) students' performance on knowledge assessment (DC5.3) and (d) students' time spent per inquiry phase (DC5.4)
- **D-DC6:** Teachers should be able to pause and re-start a lesson at a later time
- **D-DC7:** Teachers and students should be able to access a science education lesson with different devices (desktop or mobile devices) (DC7.1) and personalize the interface according to their accessibility preferences (DC7.2)

Organization for Economic Co-operation and Development (OECD) (2013). PISA 2012 assessment and analytical framework: mathematics, reading, science, problem solving and financial literacy.

The ISE Delivery Tool: Implementing D-DC1 - How to Access the ISE Delivery Tool? – 1/2





The ISE Delivery Tool: Implementing D-DC1 - How to Access the ISE Delivery Tool?– 2/2

Teacher Login Page

Student Login Page

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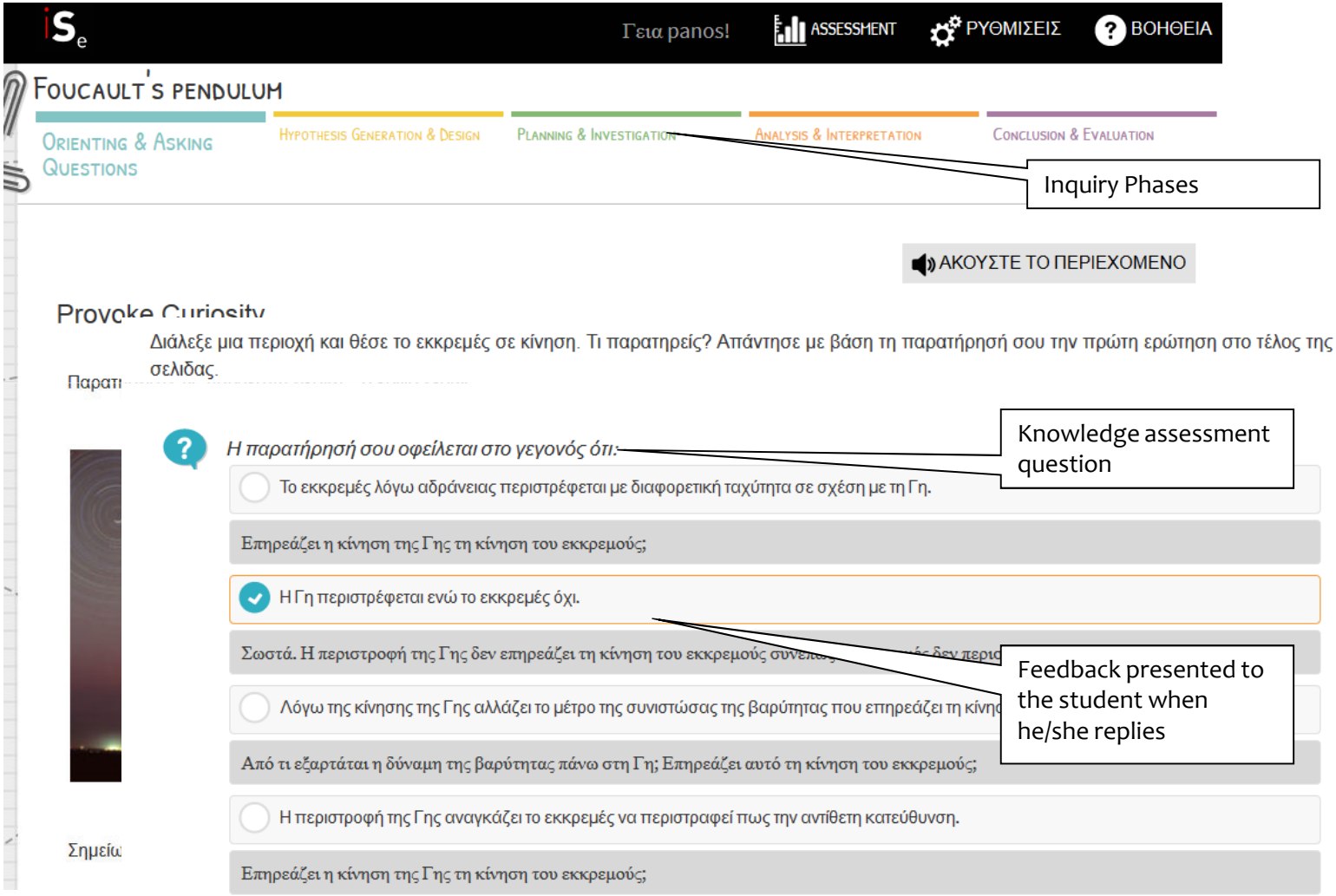
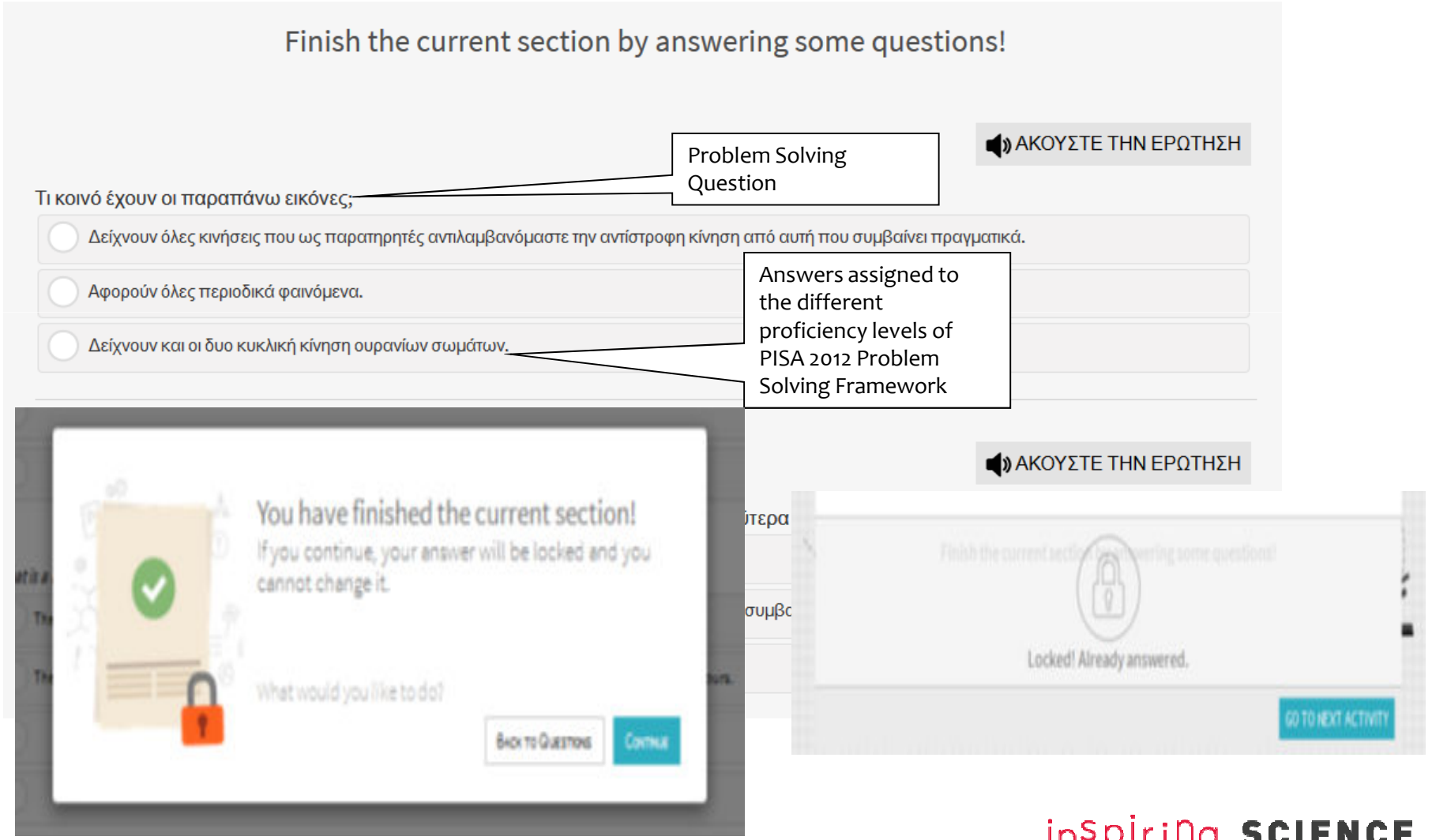
The ISE Delivery Tool: Implementing D-DC2 - Student Enrolment and Execution



The ISE Delivery Tool: Implementing D-DC2 - Student Assessment of Problem Solving Competence



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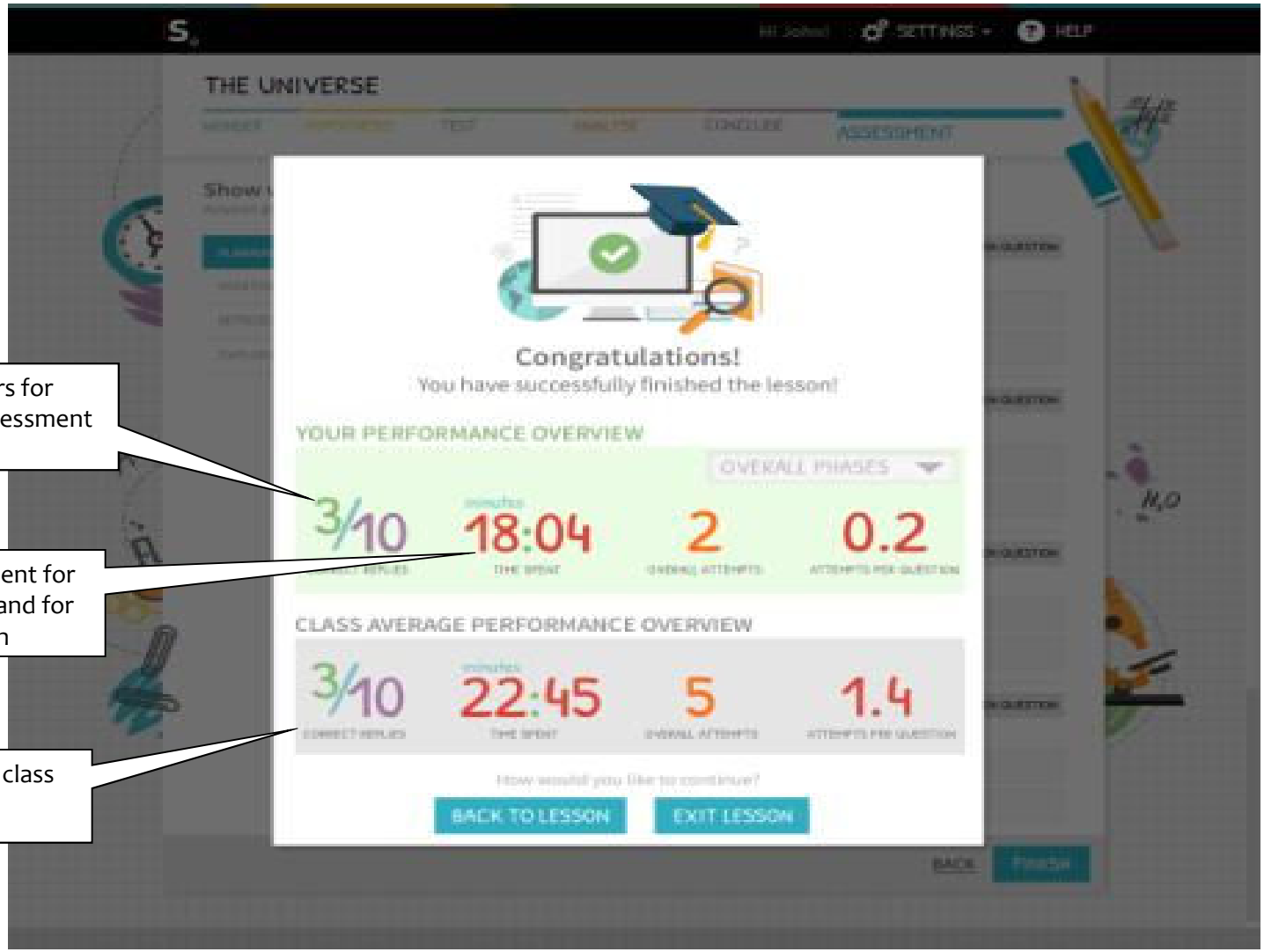
The ISE Delivery Tool: Implementing D-DC3 - Student Performance



Correct answers for knowledge assessment questions

Average time spent for the each phase and for the whole lesson

Comparison with class performance

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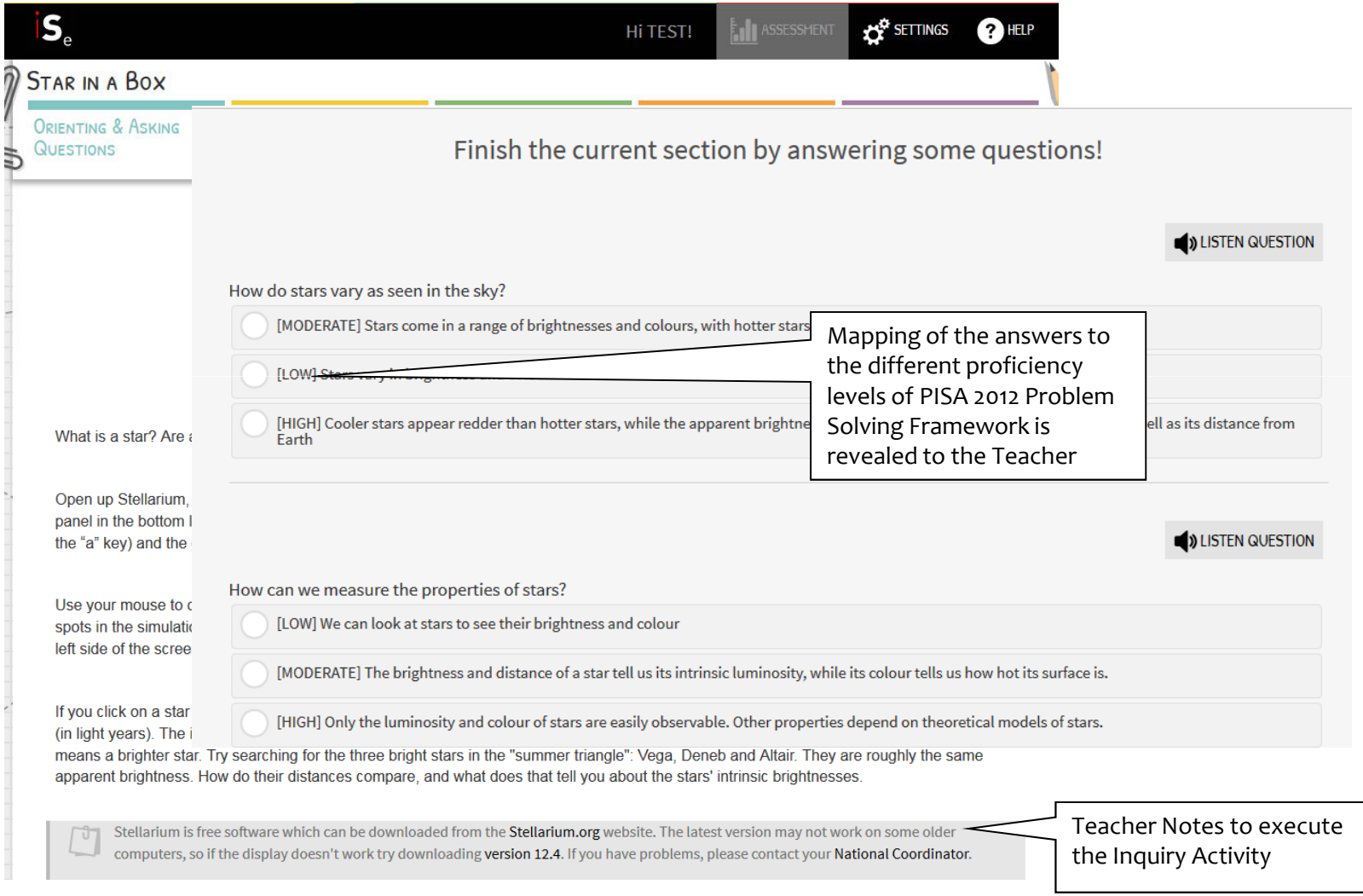
The ISE Delivery Tool: Implementing D-DC4 - Teacher Enrolment (Augmented View)



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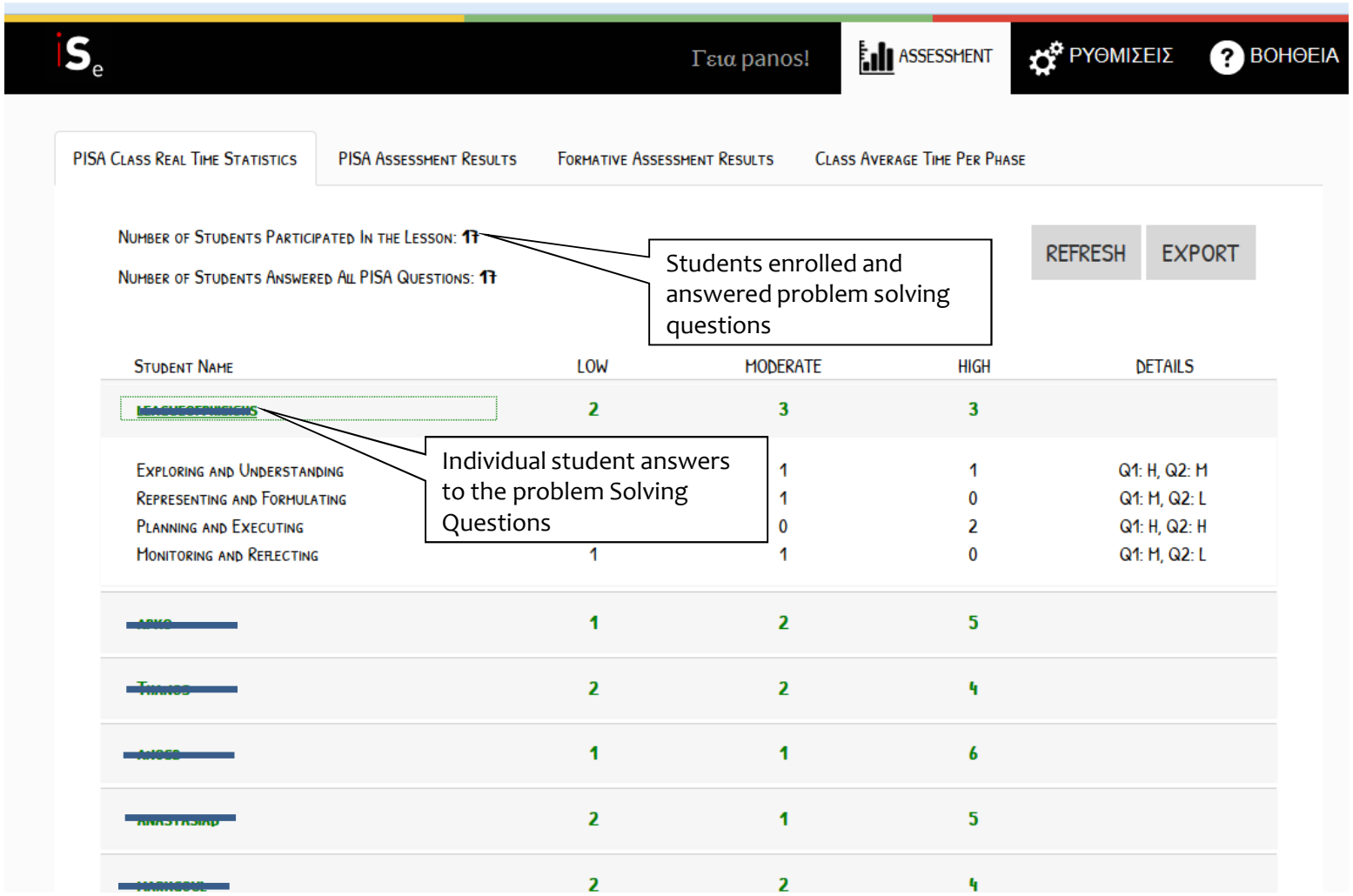
The ISE Delivery Tool: Implementing D-DC5.1 - Students' Monitoring – 1/4



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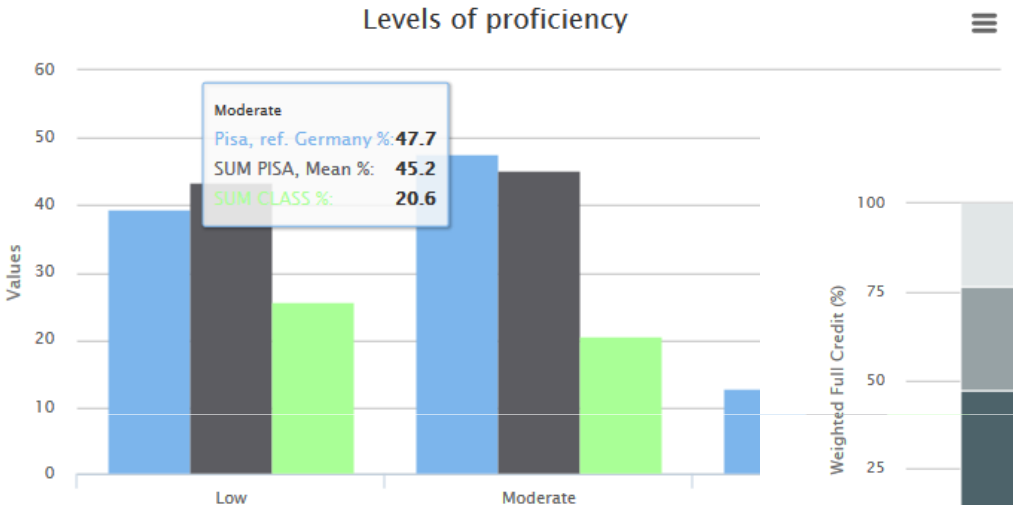
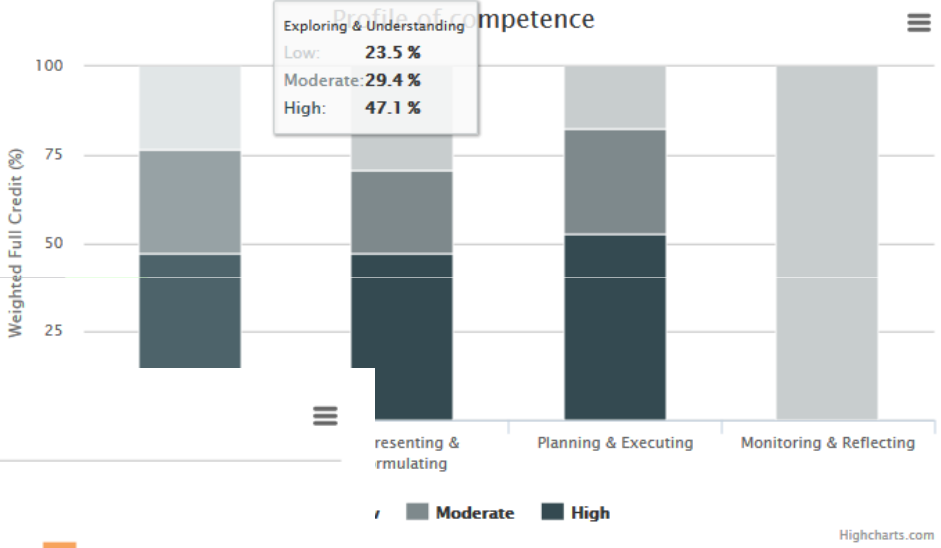
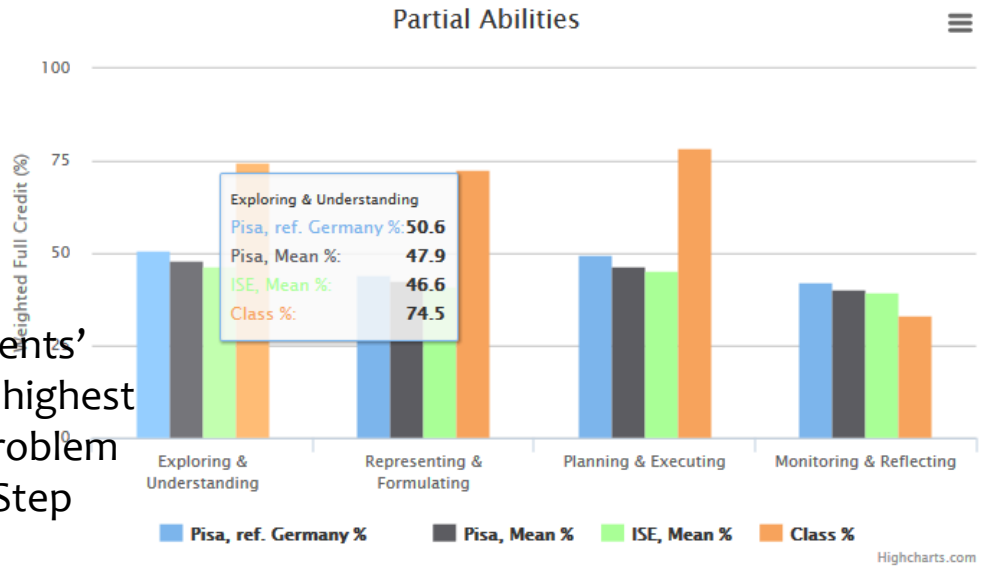
The ISE Delivery Tool: Implementing D-DC5.2 - Students' Monitoring – 2/4



% of Students' Answers per proficiency levels





% of Students' achieved at highest level per Problem Solving Step

% of Students' per proficiency level and per Problem Solving Step

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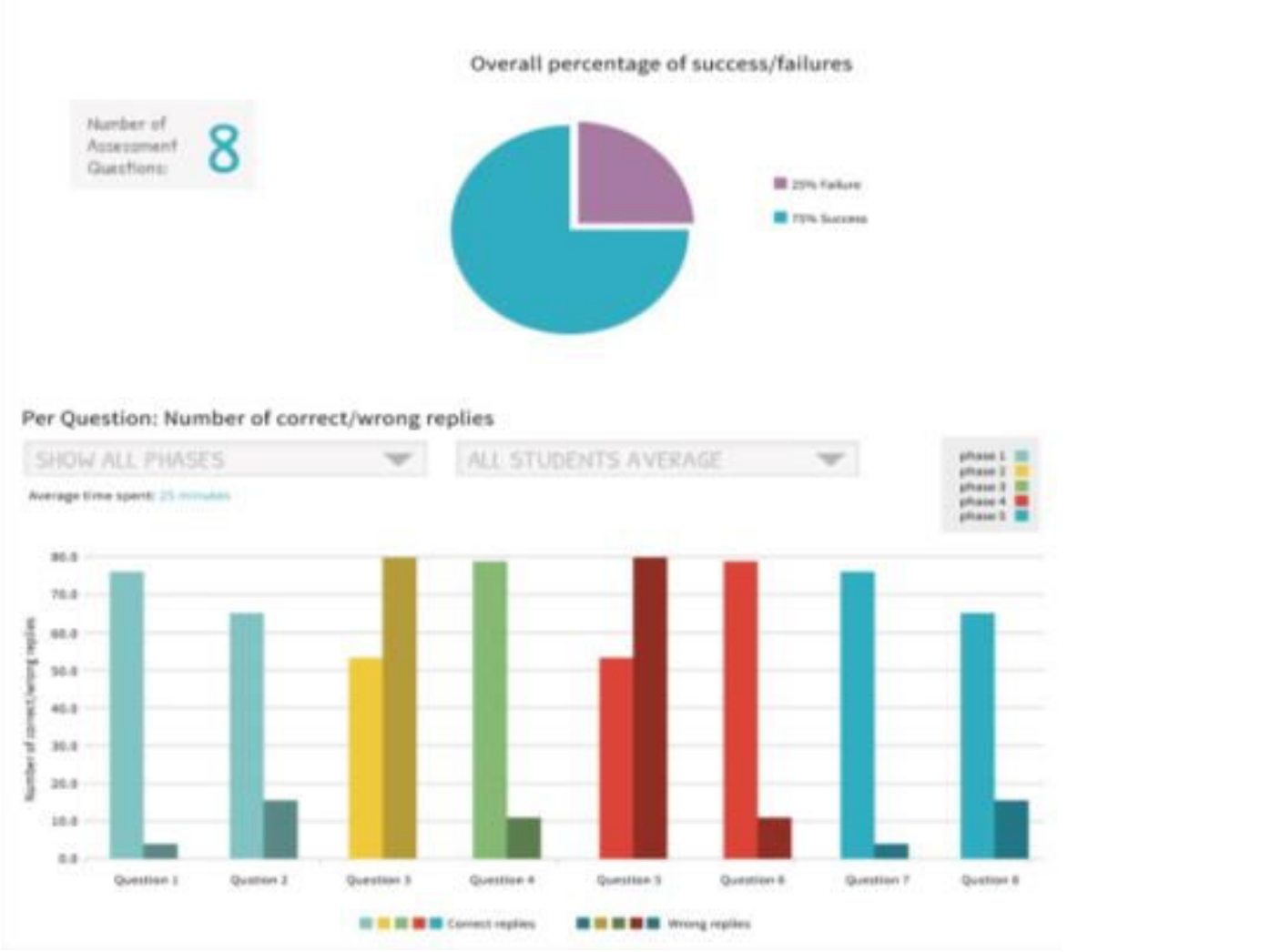
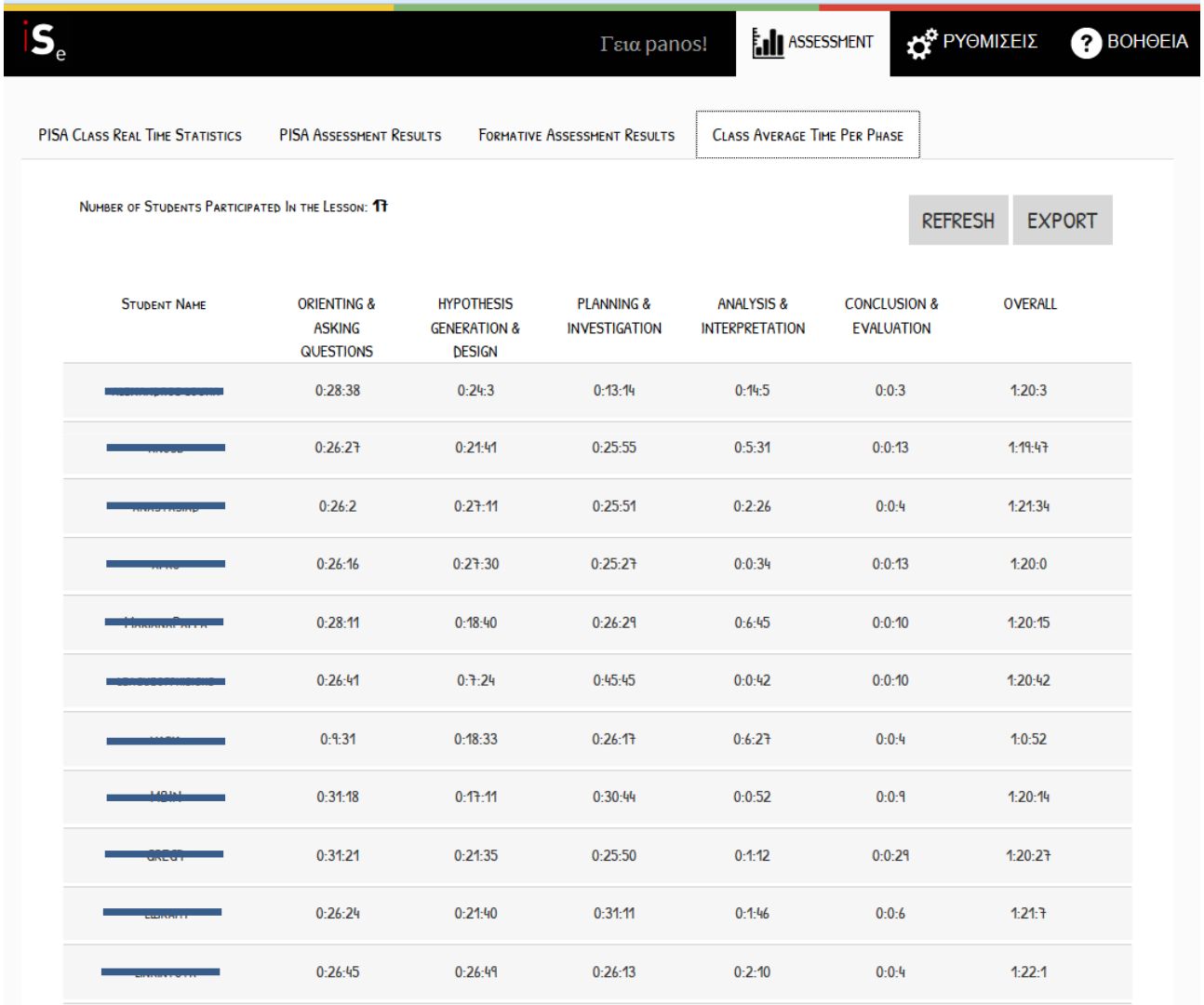
The ISE Delivery Tool: Implementing D-DC5.3 - Students' Monitoring – 3/4

Visualization of students' performance at knowledge assessment questions



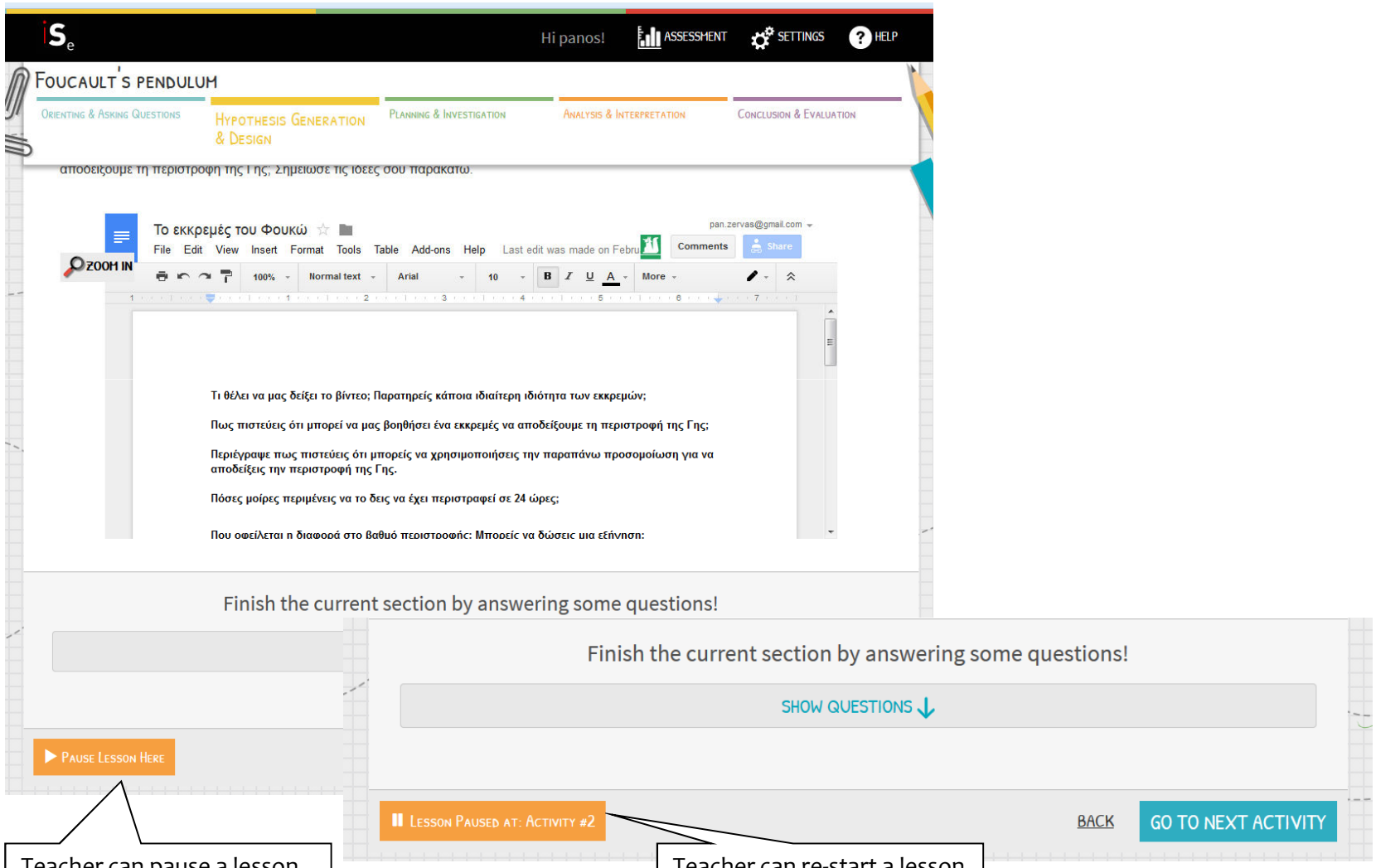
The ISE Delivery Tool: Implementing D-DC5.4 - Students' Monitoring – 4/4

Students' time spent per inquiry phase



Student Name	ORIENTING & ASKING QUESTIONS	HYPOTHESIS GENERATION & DESIGN	PLANNING & INVESTIGATION	ANALYSIS & INTERPRETATION	CONCLUSION & EVALUATION	OVERALL
[redacted]	0:28:38	0:24:3	0:13:14	0:14:5	0:0:3	1:20:3
[redacted]	0:26:27	0:21:41	0:25:55	0:5:31	0:0:13	1:19:47
[redacted]	0:26:2	0:27:11	0:25:51	0:2:26	0:0:4	1:21:34
[redacted]	0:26:16	0:27:30	0:25:27	0:0:34	0:0:13	1:20:0
[redacted]	0:28:11	0:18:40	0:26:29	0:6:45	0:0:10	1:20:15
[redacted]	0:26:41	0:7:24	0:45:45	0:0:42	0:0:10	1:20:42
[redacted]	0:9:31	0:18:33	0:26:17	0:6:27	0:0:4	1:0:52
[redacted]	0:31:18	0:17:11	0:30:44	0:0:52	0:0:9	1:20:14
[redacted]	0:31:21	0:21:35	0:25:50	0:1:12	0:0:29	1:20:27
[redacted]	0:26:24	0:21:40	0:31:11	0:1:46	0:0:6	1:21:7
[redacted]	0:26:45	0:26:49	0:26:13	0:2:10	0:0:4	1:22:1

The ISE Delivery Tool: Implementing D-DC6 - Pause and Re-Start Lesson



Teacher can pause a lesson at the end of each inquiry phase

Teacher can re-start a lesson from where the lesson was paused

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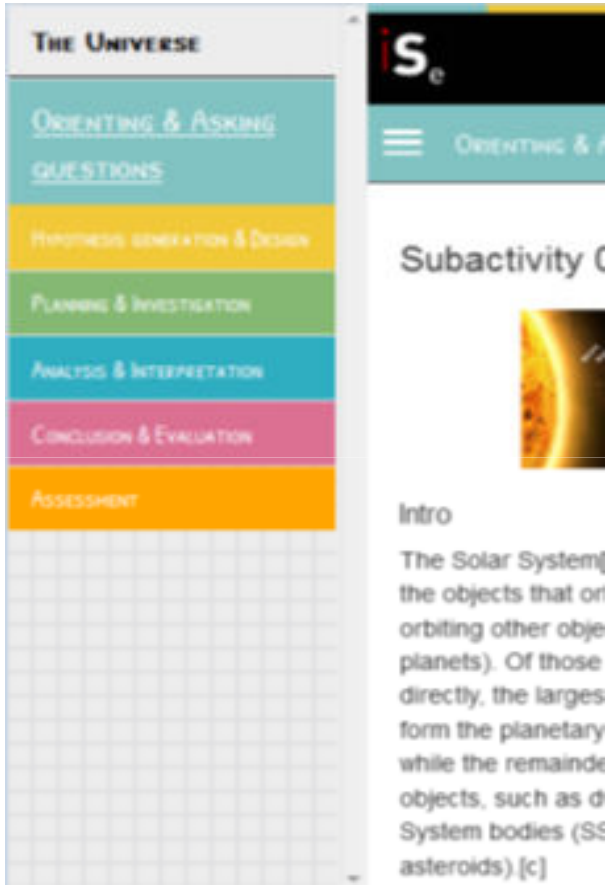
The ISE Delivery Tool: Implementing D-DC7.1 - Mobile Devices Compatibility

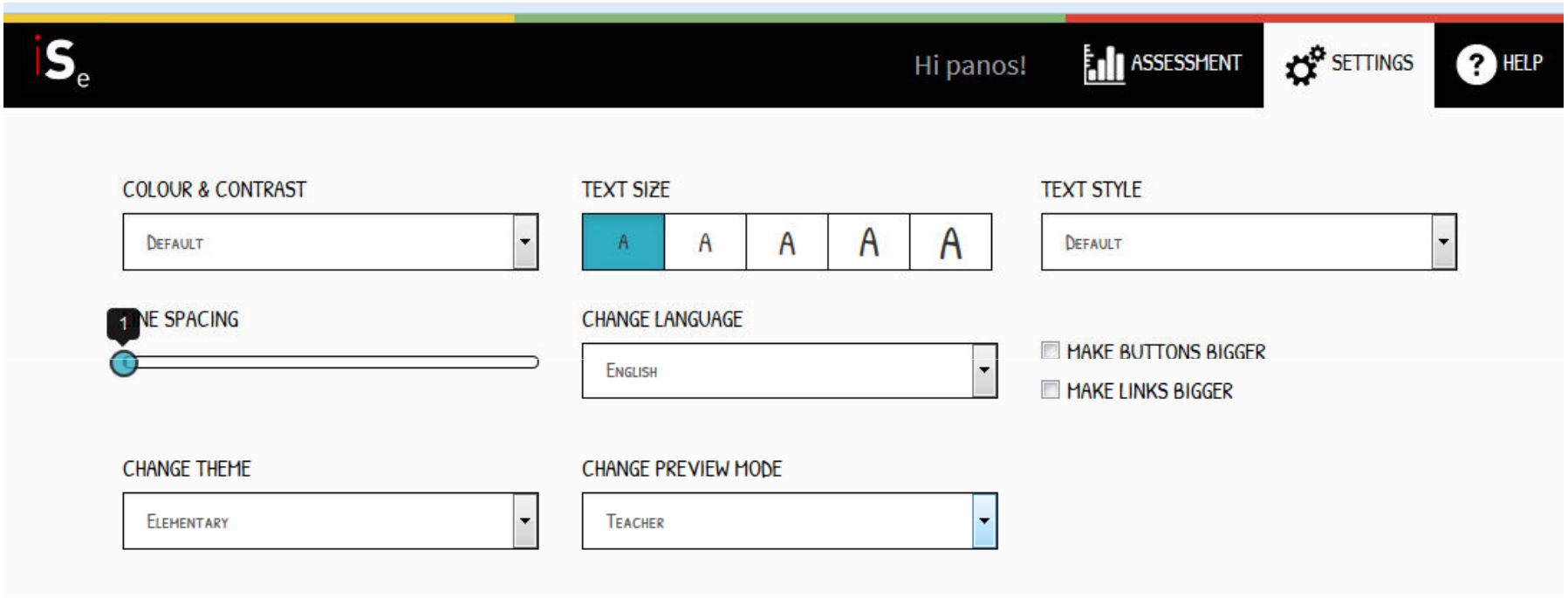
Desktop Mode



Mobile Device Mode

(responsive behavior – the navigation bar with the inquiry phases is transferred to the left)

The ISE Delivery Tool: Implementing D-DC7.2 - Accessibility Features



The teacher/student is able to change the appearance from the top bar

Thank you for your attention!!