International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2015, Vol. 11, Issue 2, pp. 184-228

A narrative approach to studying the diversification of inquiry learning across instructional settings

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ABSTRACT

In this study we used a narrative approach to investigate the function that digital, interactive tools can fulfill in inquiry teaching and learning. Such a narrative can be conceived of as 'talking through' a lesson in which a teacher supports inquiry with technology. By subsequently coding these narratives, we studied the functions that tools can fulfill related to certain learning activities and instructional settings. We created a template by distilling the coded functions of these tools. This template can be used to find alternative pedagogical functions for tools, alternative learning activities to support with a tool, and alternative instructional settings for use of the tool as educational support. Our template can support the alignment of these different aspects of tool-supported, inquiry-based learning by presenting them in a structured way.

Keywords*: educational technology, inquiry learning, narrative, science education, teaching*

INTRODUCTION

Inquiry is a central component of science education (Hofstein & Lunetta 2004). When students learn according to an inquiry approach, they take on a more active role in their learning processes. This active role is vital, as research shows that passively listening to lectures or watching demonstrations yields small learning gains (Crouch & Mazur 2001; Wieman & Perkins 2006). Having students learn via an inquiry approach can be effectively supported by technologies, such as computer simulations. However, with regard to computer simulations as supports for inquiry learning, the research field has primarily investigated the effectiveness of pedagogical interventions in the context of students learning individually or in small groups, and less in the context of whole-class teaching (Rutten, van Joolingen & van der Veen 2012). A possible consequence is that opportunities for effective teacher support when implementing tool-supported inquiry learning remain underutilized. Teachers can, for example, focus students' attention on aspects of a phenomenon that they know are associated with misconceptions (Webb 2008). Teachers can also deliberately create a brief moment of confusion to draw students' attention, by showing aspects of phenomena that are counterintuitive (Dowd 2012).

The process of inquiry learning can be conceptualized in diverse ways. There is no 'gold standard' (Bell et al. 2010). The idea that the process of inquiry learning can be conceived as a fixed pattern is not even in line with the basic nature of science, which presupposes a great deal of freedom. This freedom can be inconvenient for implementation in school practices, as a fixed pattern of inquiry learning 'steps' can be nicely executed within an hour-long lesson. However, such practices have nothing to do with authentic inquiry (Windschitl, Thompson & Braaten 2008). Caution is warranted concerning the idea that inquiry learning consists of 'steps' that must be completed before one can proceed to the next 'step'. As Pedaste and colleagues (2015) state: "...inquiry-based learning is not a prescribed, uniform linear process. Connections between the phases may vary depending on the context". It is important to approach inquiry learning from a holistic perspective by considering the different learning activities in relation to each other, to prevent students from getting a distorted conception of what inquiry is (Chen 2010). In this study, we use the term 'authentic inquiry' to refer to this holistic perspective. This implies that after completing each learning activity, a student/teacher must decide what next learning activity is most appropriate as a follow-up. This could be a 'step' forward, but it can also be a return to an earlier learning activity, as when it is necessary to collect more data before moving on.

Research on the effectiveness of tool-supported science pedagogies is often based on the following learning activities: *predict*, *observe*, *explain* (Hennessy et al. 2007). Research on supporting inquiry learning with computer simulations generally conceives of the inquiry cycle as consisting of

orientation, *stating hypotheses*, *performing an experiment*, *drawing conclusions*, and continuing with a new *orientation* (de Jong & van Joolingen 1998). There appears to be wide variety in conceptualizations of the process of inquiry learning. In their comparative research, Bell and colleagues (2010) distill nine distinct learning activities making up the process of (collaborative) inquiry learning: *orienting and asking questions*; *hypothesis generation*; *planning*; *investigation*; *analysis and interpretation*; *model*; *conclusion and evaluation*; *communication*; and *prediction*. In the present article we describe inquiry learning processes in terms of five distinct learning activities. Our attempt to merge inquiry processes in a conceptually consistent way resulted in the following five learning activities: *orienting and asking questions*, *hypothesis generation and design*, *planning and investigation*, *analysis and interpretation*, and *conclusion and evaluation*, which we describe below. Our choice of these five activities is not conceptually based, but aims at alignment with the specifications of the European project *Inspiring Science Education* (http://www.inspiringscience.eu). Our descriptions of the five inquiry learning activities are inspired by the compilation by Bell and colleagues (2010) and by descriptions of learning activities from the project *Science Created by You* (de Jong et al. 2010; de Jong et al. 2012):
http://scy-net.eu/scenarios/index.php/The_Scenario_Repository.

- **Orienting and Asking questions**

The process of inquiry can be focused on answering a question, but also on other goals, such as investigating a controversial dilemma or solving a problem. A teacher can introduce this activity with a classroom discussion and support it, for example, with narratives, videos, or simulations. Within the teacher-provided framework for the learning activities, the students' involvement in discussions can be monitored. They can take notes, ask questions, and discuss the content. In order to be able to formulate learning goals, it must be clear what knowledge and skills the students already have, where there are gaps, and where information can be found to fill those gaps. Formulating questions can be facilitated by structuring the question (problem/case) by identifying relevant limitations and variables. Knowing when the learning activity has been successfully completed requires clarifying the goals that should be achieved, or the criteria that should be met.

- **Hypothesis generation and Design**

Together with students' prior knowledge and the notes they have taken, the structure of the question (problem/case) forms the basis for formulating hypotheses, which can be considered as supposed relations between measurable dependent and independent variables. It is difficult for students to formulate proper hypotheses on their own. This learning activity therefore requires appropriate support (de Jong & van Joolingen 1998). The process of generating hypotheses and designing can take several approaches, depending on the focus of inquiry. To test hypotheses, an experiment can be set up. For problem resolution, relating a hypothesis to the data allows for checking whether the hypothesis solves the problem. Another approach to investigating hypotheses is to design a model by building a physical or virtual artifact. For example, students can design a house to investigate influences on CO_2 emissions. The appropriateness of models can be evaluated by relating it to the notes that students made during the learning process.

- **Planning and Investigation**

Clearly formulated hypotheses facilitate planning of the work process. Planning includes determining the order of activities and intermediate goals, which tools and/or data to use, a clear timeline, and division of these activities among the participants. Investigations can be performed by conducting experiments or designing artifacts, using physical or virtual tools.

▪ **Analysis and Interpretation**

Teachers can support students' process of data investigation by organizing the data collected and by identifying key issues related to interpreting the data. When solving problems, solutions found by experts can be examined and compared with the students' own solutions for the same problem. For investigation of controversial cases, different perspectives on approaching the case can be analyzed, and the value of different information sources can be evaluated. These processes can generate new questions for further inquiry.

▪ **Conclusion and Evaluation**

Arriving at conclusions in the inquiry process can mean achieving consensus about a solution to a problem, producing a common artifact, or synthesizing views to arrive at a mutual decision. The evaluation process can be facilitated by presenting conclusions to a broader audience, as this allows for replication and/or endorsement of the presented results. As it is important not only to arrive at a conclusion, e. g., solving a problem, but also to have actually learned something, reflection is necessary to allow for recognition of similar problems (questions/cases) in the future, transfer of knowledge to such situations, or the ability to apply the learned strategy. Besides evaluating one’s own outcomes, it can also be interesting to evaluate others’ outcomes and determine the extent to which they meet the criteria set. Comparing the collected data to such criteria can prompt subsequent refinement of the conceptual model. When determining whether learning goals are achieved, it can be valuable for future inquiry activities to identify what factors have been facilitators or barriers to attainment of the goals.

The goal of the project *Inspiring Science Education* is to stimulate the implementation of tool-supported inquiry learning on a large scale in classrooms across Europe. The project is financed by the European Union. The main authors of this article are participants in the work package that is responsible for creating the pedagogical foundation of the project, on which the technological infrastructure will be based. All co-authors of this article are collaborating partners in this work package, from institutions across Europe. We chose the following two ideas related to diversification of inquiry learning as central in our pedagogical foundation:

- The order of learning activities should vary. In other words, recognition of the nature of authentic inquiry practices means that there should be freedom in the order of learning activities.

- The instructional setting should vary. In other words, inquiry learning activities should focus just as well on the individual, on small groups, and on the whole-class context.

The main purpose of this article is to gain insight into the supportive functions that tools can fulfill for inquiry learning processes in relation to the above-mentioned ideas. Therefore, we had all authors set up fictitious tool-supported, inquiry-based lessons, which we call ‘narratives’. A narrative in the context of the project *Inspiring Science Education* can be conceived of as ‘talking-through’ an implementation of an inquiry-based teaching and learning scenario supported with digital, interactive tools. In other words, it is a storyline. The difference between a lesson plan and a narrative is that a lesson plan describes a sequence of teaching and learning activities, while a narrative comes closer to teaching practice, as it reflects what could actually happen with a lesson plan when implemented. As such, a narrative corresponds to a certain extent with a lesson plan, as it contains a sequence of learning activities, triggered by teacher and student actions, combined with the use of tools. Narratives come closer to what really happens in teaching practices, as they can also contain:

- intentions and experiences of the teacher and the students;

- specific information on instructional settings: whether learning activities are on a whole-class, small group, or individual level;

- dynamic interplay between learning activities: e.g., having the students switch back and forth between different learning activities before moving on to the next.

Because of these extra 'ingredients', it is possible that the same lesson plan can lead to completely different narratives when implemented by different teachers. The teachers' personal characteristics can flavor a lesson plan in divergent ways, thus leading to the creation of individual narratives. We coded all narratives on a functional level, answering the following question: what are the specific functions a tool fulfills in that inquiry learning activity in that instructional setting? The creation of a template summarizing the results of this coding process allows for transference of this functionality to other contexts. The present article therefore has the following research purposes:

- *Explore ways to diversify inquiry learning by varying instructional settings and the order of learning activities.*

- *Distill functional diversity into a template to allow for transferred application to other instructional contexts.*

METHOD

All authors were requested to provide a narrative on how a teacher uses digital, interactive tools to support inquiry-based learning. They received the following request:

- **Set up a narrative in line with the five inquiry-learning activities**

  Please provide us with a narrative based on the five inquiry-learning activities related to digital, interactive tools. While setting up your narrative, please pay attention to the following concerns:

  a. To what degree is the teacher intended to take certain actions and to follow a certain approach?
  b. What are the specific actions for the teacher and the students during each learning activity?
  c. In what way does your narrative reflect the dynamic reality of inquiry? In other words, where does it diverge from a standard 1-2-3-4-5 sequence of learning activities?
  d. How do you vary the instructional setting between different learning activities?
  e. If you can contact a teacher with inquiry teaching experience: does he/she have suggestions for improvement of your narrative?

We provided all authors with a list with suggestions of tools that they could use in their narratives. This list includes:

- online labs and applications, such as
  - Faulkes Telescope (www.faulkes-telescope.com, a network of robotic telescopes),
  - PhET simulations (phet.colorado.edu, a simulation suite for science and math);
- educational repositories and portals, such as
  - Natural Europe (education.natural-europe.eu, activities designed by Natural History Museums' educators),
  - Open Science Resources (www.openscienceresources.eu, a repository of digital tools

and learning activities);

- and, advanced technological applications, such as
  - F1 in Schools (www.f1inschools.com, a technology competition),
  - Science Center to Go (www.sctg.eu, science exhibits based on augmented reality).

The narratives based on the five inquiry-learning activities that were created by all authors can be found in the Appendix.

Analysis

Following the creation of narratives by all authors, the narratives were coded. This coding process involved extraction of certain aspects of the narratives in a structured way, specifically the function that the tools were fulfilling in the inquiry process. Following such a structured coding approach makes it possible to discover general trends in specific aspects of the narratives, while considering the collection of narratives as a whole. This coding process was conducted on the subsection of the narratives that the authors subdivided according to instructional setting (*whole-class*, *small groups* or *individually*) and inquiry-learning activity (*Orienting and Asking questions*, etc.). The purpose of this coding process was to clarify the supportive function that each selected tool fulfills in the processes of teaching and learning, for each learning activity and instructional setting. We expected that the pedagogical functions that the tools fulfill would be most clearly revealed by the verbs in sentences that refer to the use of tools. We expected that the function of tool characteristics was stressed more by the verbs, compared to the nouns/objects to which the verbs refer. For each cell in the appendix, the verbs express the supportive function of the tools (e.g., using Google Docs to 'create'), potentially combined with a noun or object (e.g., 'creating hypotheses'). To be eligible for coding, both the verb and the noun or object had to be specific (e.g., in 'working on the whiteboard', 'working' is too unspecific as a learning activity, and 'whiteboard' is too unspecific as a tool). In the eventual template, we therefore retained only the verbs or nouns/objects that specifically referred to inquiry learning activities. We acknowledge that there are exceptions to this rule of thumb, as on occasion functionality was expressed more by the noun/object, which necessitated some flexibility in choosing to code verbs or nouns/objects. Coding of the verb versus the noun/object depended on which of them most characteristically referred to the function the tool fulfills. For example, in 'compare sources' the word 'compare' was coded, but in 'formulate hypothesis' the word 'hypothesis' was coded, as we considered 'comparing' and 'hypothesizing' to be referring most directly to the tool's function in that activity.

By making an inventory of how the specific tools are linked to their functions, we assigned each specific tool to one of several main tool categories. In the cells in Table 1, the tools and functions are ordered alphabetically, and duplicate functions are removed. Besides the main tool categories and associated functions, Table 1 contains all specific tools associated with each tool category.

RESULTS & DISCUSSION

Table 1 shows the template summarizing our findings. This table was composed by arranging in alphabetical order the extracted coded inquiry-learning functions shown in the narratives in the appendix, after removing duplicates.

***Table 1**: Template linking the inquiry-learning activities to tool categories, their functions and examples of specific tools**

inquiry-learning activity	instructional setting		
	whole class	small groups	individually
Orienting and Asking questions	**3D environment** (discussing; introducing | *Genome Island, Second Life, Stellarium*) **documentation** (creating; formulating; providing; questioning; searching; selecting; showing; triggering | *blog, Google Docs, Padlet, wiki*) **measurement** (analyzing; discussing | *Go!Motion, Logger Pro, SalsaJ, Tracker*) **simulation** (encouraging; introducing; training | *Gizmos, PhET, Tick model, Virtual Lab*) **video** (discussing; presenting; provoking; showing | *YouTube*)	**3D environment** (exploring | *Genome Island, Second Life, Stellarium*) **documentation** (accessing; assigning; choosing; consolidating; deciding; formulating; narrowing; posting; recognizing; requesting; selecting; steering | *blog, Google Docs, Padlet, wiki*) **simulation** (collecting | *Gizmos, PhET, Tick model, Virtual Lab*)	**3D environment** (comparing; exploring; observing; verifying | *Genome Island, Second Life, Stellarium*) **documentation** (developing; finding; looking up; posting; selecting | *blog, Google Docs, Padlet, wiki*) **gaming** (enriching; exploiting; familiarizing; investigating; playing; positioning | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **information** (collecting; searching | *Google*) **simulation** (exploring; finding; inserting; looking; moving; playing; watching; wondering | *Gizmos, PhET, Tick model, Virtual Lab*)
Hypothesis generation and Design	**simulation** (asking; formulating; voting | *Gizmos, PhET, Tick model, Virtual Lab*)	**3D environment** (documenting; formulating; grouping; hypothesizing; investigating | *Genome Island, Second Life, Stellarium*) **documentation** (defining; designing; documenting; formulating; hypothesizing; writing | *blog, Google Docs, Padlet, wiki*) **gaming** (designing; formulating; hypothesizing; identifying; testing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **information** (choosing; designing; searching; writing | *Google*) **mind-mapping** (brainstorming | *Bubbl.us, Xmind*) **simulation** (formulating; generating; solving | *Gizmos, PhET, Tick model, Virtual Lab*)	**gaming** (hypothesizing; playing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **simulation** (evaluating | *Gizmos, PhET, Tick model, Virtual Lab*) **voting** (measuring; visualizing | *Socrative*)
Planning and Investigation	**3D environment** (presenting | *Genome Island, Second Life, Stellarium*) **mind-mapping** (creating | *Bubbl.us, Xmind*)	**3D environment** (acquiring; creating; observing; planning; recording; retrieving; supporting; telling | *Genome Island, Second Life, Stellarium*) **documentation** (choosing; collecting; measuring; monitoring; setting up; updating; writing | *blog, Google Docs, Padlet, wiki*)	**3D environment** (creating; telling | *Genome Island, Second Life, Stellarium*) **documentation** (completing, looking up | *blog, Google Docs, Padlet, wiki*) **gaming** (calculating; measuring; observing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*)

		gaming (changing; deciding; experimenting; testing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **measurement** (collecting; conducting; measuring; planning; presenting; processing | *Go!Motion, Logger Pro, SalsaJ, Tracker*) **mind-mapping** (associating; creating; proposing | *Bubbl.us, Xmind*) **simulation** (accessing; completing; constructing; deciding; reconfiguring; testing | *Gizmos, PhET, Tick model, Virtual Lab*)	**mind-mapping** (preparing; reading | *Bubbl.us, Xmind*) **simulation** (testing | *Gizmos, PhET, Tick model, Virtual Lab*)
Analysis and Interpretation	**3D environment** (presenting | *Genome Island, Second Life, Stellarium*) **documentation** (interpreting; representing; storing | *blog, Google Docs, Padlet, wiki*) **gaming** (arguing; comparing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*)	**3D environment** (analyzing; comparing; discussing; matching | *Genome Island, Second Life, Stellarium*) **documentation** (analyzing; collecting; creating; documenting; evaluating; examining; highlighting; interpreting; placing; presenting; testing | *blog, Google Docs, Padlet, wiki*) **gaming** (analyzing; checking; comparing; presenting | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **questionnaire** (analyzing; creating; interpreting | *LimeSurvey, SurveyMonkey*)	**documentation** (comparing; finding; presenting; reproducing | *blog, Google Docs, Padlet, wiki*) **gaming** (answering | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **questionnaire** (analyzing; interpreting | *LimeSurvey, SurveyMonkey*)
Conclusion and Evaluation	**documentation** (aggregating, asking, collecting, commenting, concluding, confirming, discussing, evaluating, explaining, gathering, presenting, publishing, rejecting | *blog, Google Docs, Padlet, wiki*)	**documentation** (checking; clarifying; communicating; concluding; creating; describing; discussing; entering; explaining; giving; placing; presenting; providing; publishing; recommending; refining; simulating; writing | *blog, Google Docs, Padlet, wiki*)	**documentation** (accessing; assessing; concluding; documenting; drafting; filling; identifying; understanding; writing | *blog, Google Docs, Padlet, wiki*) **gaming** (comparing; showing | *DNA Damage, Interactive Human Body, LHC game, Shooting Stars*) **questionnaire** (voting | *LimeSurvey, SurveyMonkey*)

Note. *Words in bold refer to categories of digital, interactive tools; words in normal print refer to the tool's functions for inquiry-based teaching and learning; words in italics refer to examples of specific tools (in alphabetical order under each instructional setting).

Our template in Table 1 interconnects all investigated aspects of tool-supported inquiry learning during our five identified inquiry learning activities: the tool categories, their functions, and specific examples of such tools. For example, tools for documentation are used across the different learning activities and instructional settings, but mostly when setting up the learning activities and when wrapping up. Gaming seems more appropriate for the learning activities of *Hypothesis generation and Design*, *Planning and Investigation* and *Analysis and Interpretation*. Tools that appear to be often linked with specific learning activities are: voting tools with *Hypothesis generation and Design*, and mind-mapping tools with *Planning and Investigation*. Specific links that seem to emerge between tools and instructional settings are: video for the whole-class setting, and questionnaires for settings on a smaller scale (small groups and individually).

Most learning-activity tool functions are associated with the small group instructional setting. Apparently, tool-supported inquiry-based learning is considered especially suitable for that setting. Some functions of tools used during individual learning activities are potentially relatively more time-consuming, such as reading and writing. Learning-activity tool functions that seem particularly appropriate for the small group instructional setting are: *discussing*, *proposing*, and *brainstorming*.

Roles that a teacher can have are clarified by the learning-activity tool functions associated with the whole-class instructional setting. Some typical teacher activities are: *introducing*, *provoking*, and *explaining*. The template for the five inquiry-learning activities shows how the teacher has specific roles at the beginning when setting the stage, and at the end when wrapping up. Activities that can be used to set the stage are, for example, *questioning*, *triggering*, and *encouraging*. After setting up in the whole-class setting, the focus of activities can be shifted to working in small groups and/or working individually. When wrapping up the lesson, the teacher can regain a more central role by using activities such as: *aggregating*, *concluding*, and *evaluating*.

The present template clarifies that the five learning activities are in fact umbrella concepts, and illustrates the richness of functions that each of these concepts encompasses. Therefore, our template can support the designation of functions to tools when setting up teaching and learning scenarios. There are several ways in which teachers can use this template to support planning the process of tool-supported inquiry learning. Below, we provide three examples of such applications, each illustrated by a short vignette.

- **finding suggestions for supporting a learning activity in an alternative instructional setting**
  Ingrid organized the *Planning and Investigation* activity by having students work in groups. She also had in mind that the students would continue to work in groups during the *Analysis and Interpretation* activity. However, she notices that class time is almost over. There is not enough time for more group work. Based on the template she decides to change the *Analysis and Interpretation* activity into an individual activity: she assigns individually posting interpretations of the data on a shared Padlet wall as homework. The next lesson will start with evaluating what everyone has posted.

- **finding suggestions for supporting a learning activity with a different kind of tool**
  Sam is planning an inquiry-based lesson on the subject of planetary orbits. He likes to begin the lesson by showing some YouTube videos to spark students' curiosity. The previous time he conducted this lesson, he continued by having the students formulate hypotheses while using the PhET simulation *Gravity and Orbits*. This time, he wants to try something different. In the template he notices that an alternative approach is to support this learning activity by having students play with the game Shooting Stars (www.prace-ri.eu/daretothinktheimpossible/shootingstars, a simulation of orbiting planets). In other words,

he switches from the simulation approach to a gaming approach, while still supporting the learning activity of *Hypothesis generation and Design*.

- **finding suggestions for possible functions for an alternative tool**
  Eve stumbled upon Mindmeister (www.mindmeister.com, a mind-mapping website) and wonders how she could incorporate this tool in an inquiry-based lesson. In the template she notices that such a mind-mapping tool is suitable for having students in small groups brainstorm on their hypotheses to be investigated. Another example is to collectively investigate hypotheses during a mind-mapping activity in the whole-class setting.

CONCLUSION

The template we have created can help teachers in orchestrating inquiry-based, tool-supported lessons by offering suggestions for combinations of learning activities, tools, and instructional settings. The purposes of this article were to explore ways to diversify inquiry learning by varying instructional settings and the order of learning activities, and to distill functional diversity into a template allowing for transferred application to other instructional contexts. We based our templates on coding tool-based, inquiry-learning narratives. The resulting templates show a wide variety of functions that tools can support when approaching teaching and learning from an inquiry perspective.

Teaching is a potentially complex affair, as a multitude of aspects must be dealt with. Technological developments can be promising for implementation in educational settings. However, an increase in the facets that must be taken into account can make teaching even more demanding. Even though technology implementations can increase the complexity, they can offer possibilities of making education more effective, varied, and fun. A template such as the one that we have developed can make it easier to cope with increased complexity, as it allows for a structured way of thinking about the alignment between learning activities, instructional settings, and the functions that digital, interactive tools can fulfill as support for learning processes.

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APPENDIX

The appendix to this article contains the inquiry-based tool-supported teaching narratives created by the authors of this article.

1.1 Inquiry-based tool-supported teaching narrative provided by University of Twente

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	PhET simulations: Gravity and Orbits or My Solar System			Some basic exploration and wonderment: move the probe around and watch the behavior of the vector associated with it. Also she suggests that learners insert objects with a given mass and initial position and velocity and look what happens. This is an individual activity where learners play with the simulation for 20 minutes.	Iris is a physics teacher and she wants to create an inquiry activity on planetary movements and gravitation. Her main goal is that learners learn to see gravity as a field, associated with each massive object. Learners should explore situations such as elliptical, parabolic and hyperbolic trajectories as well as phenomena in the field such as equilibrium points, Lagrange points etc. In the end students should be able to understand the idea of geostationary satellites as well as the trajectories for space travel, such as a mission to Mars. 1. Iris searches the ODS/ISE repository for relevant resources for the topic she wants to teach. She finds a few relevant resources: a simulation of the planetary system, a few relevant texts and demonstration activities. [Let's assume that…] the simulation allows users to probe the gravitational field and insert objects in the system with a given mass and speed. 2. Along with the simulation she finds suggested usages. These are partly authored by the authors of the simulation, partly suggested by users who have used the simulation before. One of the uses is a blended, collective inquiry scenario. An inquiry scenario can be considered 'blended' when different instructional approaches are combined, e. g., by using technological tools as support, to allow for a more personalized learning experience. 3. Iris decides to use the blended, collective inquiry scenario. The scenario consists of four basic activities to fill: ***Orienting and Asking questions***, ***Hypothesis generation and Design***, ***Planning and Investigation***, and ***Conclusion and Evaluation***. 4. She inserts the resource in the ***Orienting and Asking questions*** template and fills this with a task for the learner that expresses some basic exploration and wonderment: move the probe around and watch the behavior of the vector associated with it. Also she suggests that learners insert objects with a given mass and initial position and
Hypothesis generation and Design	PhET simulations: Gravity and Orbits or My Solar System	Hypotheses are formulated and made explicit. Iris makes this activity a class discussion, asking students for their ideas and having a vote on which hypotheses to investigate.			
Planning and	PhET			Learners will	

<table>
<tr>
<td>Investigation</td>
<td>simulations: Gravity and Orbits or My Solar System</td>
<td></td>
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<td>again use the simulation on an individual basis, so Iris inserts the simulation in this activity together with a worksheet reminding them that they should test the hypotheses specified.</td>
<td rowspan="3">velocity and look what happens. This is an individual activity where learners play with the simulation for 20 minutes. She writes the accompanying worksheet.
5. The Hypothesis generation and Design part asks that hypotheses are formulated and made explicit. Iris makes this activity a class discussion, asking students for their ideas and having a vote on which hypotheses to investigate.
6. During the Planning and Investigation activity, learners will again use the simulation on an individual basis, so Iris inserts the simulation in this activity together with a worksheet reminding them that they should test the hypotheses specified.
7. In the Conclusion and Evaluation activity, Iris plans to collect the data by all students so she searches for a tool that allows such data aggregation. She finds one through the ODS/ISE repository – a tool utilizing Google Docs spreadsheets. She inserts that in the Conclusion and Evaluation activity.
8. Iris plans on switching back and forward between Planning and Investigation and Conclusion and Evaluation until she and her students are satisfied with the conclusions they can draw based on the data, that is, until enough data is collected to be able to confirm or reject the hypotheses. Basically both activities are planned in parallel – while working on the simulation, students can enter data on the joint spreadsheet. At certain points Iris plans to draw attention and discuss the status, resulting in more precise attempts for students to gather more data.
9. For Conclusion and Evaluation, Iris wants students to write a report. A template for the report is added to this activity.
10. After working out the scenario, Iris stores it and retrieves a URL that can be given to the students for their individual work.
11. Iris runs the lessons. For the online activities, learners can use the URL provided, that Iris has shared on the schools' electronic learning environment.
12. After the lessons, Iris records her experiences and makes a few notes accompanying the scenario. Using these notes she can retrieve, adapt and reuse the scenario. She grants other ISE users access to her recorded experience. This means when other teachers search for similar activities Iris' scenario will appear in their search results.</td>
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<tr>
<td>Analysis and Interpretation</td>
<td></td>
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<tr>
<td>Conclusion and Evaluation</td>
<td>a tool utilizing Google Docs spreadsheets</td>
<td>Iris plans to collect the data by all students so she searches for a tool that allows such data aggregation. Iris plans on switching back and forward between Planning and Investigation and Conclusion and Evaluation until she and her students are satisfied with the conclusions they can draw based on the data, that is, until enough data is collected to be able to confirm or reject the hypotheses. At certain points Iris plans to draw attention and discuss the status, resulting in more precise attempts for students to gather more data.</td>
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1.2 Inquiry-based tool-supported teaching narrative provided by University of Bayreuth

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	http://www.youtube.com/watch?v=C1_uez5WX1o&feature=related Wiki ODS portal	Johanna shows the photosynthesis song. The class discusses what plants need to be able to photosynthesize. Also the products of photosynthesis are discussed. She then shows the class the Wiki she made. The song is on it, along with other video's, animations, texts and links to other websites, that she found on the ODS portal. Also a description of the task is shown and the links to the different Groupwiki's are there. Then, the class is divided into small groups (3-4 persons).	Each group will research an aspect of photosynthesis. For example: the amount of light needed, the optimal temperature, the influence of the color of the light, the optimal carbon dioxide concentration, the difference between plants which normally stand in the sun and plants which stand in the shade, etc.	Each group member can look up information needed for their research. They can find it in the Wiki set up by Johanna. In it, information can be found that Johanna has written there, but also links to video's, animations and other.	Johanna is a biology teacher in secondary school. She created an inquiry-based project on photosynthesis for 11th grade students. First she shows the photosynthesis song (in English) after which she talks with the whole class about what plants need and produce in the process of photosynthesis. She then shows the class the Wiki she made. The song is on it, along with other video's, animations, texts and links to other websites that she found. Also a description of the task is shown and the links to the different groups are there. Then, the class is divided into small groups. Each group will research an aspect of photosynthesis, for example: the amount of light needed, the optimal temperature, the influence of the color of the light, the optimal carbon dioxide concentration, the difference between plants which normally stand in the sun and plants which stand in the shade, etc. Each group starts with writing the names of the group members in their own Groupwiki. They discuss the aspect they should investigate and look up the information they need. Then the hypothesis is formulated and written in the Groupwiki. Johanna is asked to read and comment on it. After approval the group carries on designing the experiment. In order to do so, they look up what materials are available for them and how certain measurements can be made. This again is written in the Groupwiki and approved by Johanna.
Hypothesis generation and Design	Wiki		Each group formulates the hypothesis they want to investigate. The hypothesis should be based on information found in the Wiki. The hypothesis, including (links to) the theory, is written down in the Groupwiki, which is linked to Johanna's Wiki. Johanna reads the hypothesis and after she approved it, the group can start designing the experiment.		
Planning and Investigation			The students choose what they need for the experiment and how measurements will be made in order to answer the research question. Again, this is written in their Wiki. After	The student should only look up what he needs, for example: how the amount of oxygen	

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
			approval by Johanna, the students set up their experiment. Data collected are written in the Groupwiki.	produced can be measured.	The experiment is set up, and measurements are made. Results are written down and visualized by making tables/ graphs. The students find out whether their hypothesis is confirmed or rejected. When rejected, they try to explain why. Also the students think of improvements that can be made in the experimental design and they also give suggestions for further research. Everything is written down in the Groupwiki. The learning activity ends with the whole class. Each group presents its Groupwiki, with the research performed. After each presentation, the other students can ask questions and make suggestions. Johanna decides to give each group time to improve their Groupwiki after the questions/ recommendations are made and grades each group.
Analysis and Interpretation			Students analyze the data collected, they create a graph showing the results and place it on their Groupwiki.		
Conclusion and Evaluation		Each group presents his Groupwiki, explaining what has been researched and what the outcomes are. Other students are invited to ask questions or give comments.	They draw conclusions and check whether their hypothesis is proven. They try to explain their results. Also, recommendations for improving the experiment have to be made and further research possibilities should be given. Again this is placed on the Groupwiki.		

1.3 Inquiry-based tool-supported teaching narrative provided by University of Duisburg-Essen

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Second Life: Genome Island http://slurl.com/secondlife/Genome/118/145/53 email list blog	Introduction to IBSE; Introduction on how to use Second Life (if necessary: how to register); Introduction to Genome Island: different areas, possibilities	Exploration of the island in small groups and/or individually (mostly from home);		Thomas is a biology teacher. He wants to create an inquiry-based activity in the field of genetics for upper-secondary students that have chosen biology as one of their main subjects. As introduction to the topic and the method, Thomas introduces Second Life as a virtual environment to explore the different facets of genetics and the implications on flora and fauna. In class, Thomas demonstrates how to arrive at the island and how to enter different thematic spaces. Information on this is also provided in Thomas' blog about the class or via email. The students group together in the area of the island that they want to explore. They have to agree on the exact topic they want to explore and how to present to the other groups this topic (e.g. Mendel's laws and practical effects on characteristics of animals/plants). To document their plans, the students are free to use online tools (Wikis, blogs, Flickr, etc.) or to store everything on their own computer. They provide Thomas with an outline of their experimentation plans; Thomas checks them for feasibility and approves them. The groups now start to experiment on the island; during that process, they document what they do, the results they obtain, the problems/limitations of the island they encounter, the material/knowledge they have to import from other sources, etc. The final experimentation pathway is stored in the project blog and has to be presented. Peer students then have to reproduce/"re-walk" the experimentation pathway on the island using the instructions from the blog, thus reproducing the experiments performed by other groups. At the end of the period, students give feedback on the pathways provided by other groups and compare them with their own products; a joint feedback and reflection session brings the exercise to an end.
Hypothesis generation and Design	Second Life (Flickr)		Students interested in similar topics group together inside SL; groups can also consist of just one person Each group formulates the topic and the hypothesis they want to investigate. Topics have to be documented in written format and with snapshots from the island (or stored individually or using an online tool) Thomas checks the topics and hypothesis; after approval, the group starts to investigate.		
Planning and Investigation	Second Life other sources	Each group gives intermediate presentations in class about the work done and advances in the last period.	Groups/individuals create a storyline/pathway through the island that tells the story of their investigation/experimentation and that illustrates what they have done.		
Analysis and Interpretation	Second Life blog	The groups present the complete experimentation of their topic and the results; The pathways have to be stored and provided online in the blog.		Each student has to reproduce one or more experimentation pathways.	
Conclusion and Evaluation		Wrap-up and feedback session in class		Students give feedback on the pathways they reproduced and how they see their own experimentation in comparison.	

1.4 Inquiry-based tool-supported teaching narrative provided by Coventry University's Serious Games Institute

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	a tool utilizing Google Docs spreadsheets for teachers and students to pose their questions	Sara has created an inquiry activity where either students need to pose questions that would trigger scientific investigations about understanding the DNA structure. Students select from a range of questions provided by Sara in Google document. Sara is also providing some keywords and relevant phrases for students to formulate their own questions as an alternative.	Sara has divided students into small groups (3 students each) for communally deciding the questions they are going to select on working together while formulating their own questions. Each group works on its own Google Doc and at the end Sara is consolidating each group's work to one Google Doc for feedback.	Each individual student is working individually on a Google Doc to select a pre-defined scientific question or developing his/her own question.	Sara is a biology teacher in secondary education and she is keen on enacting inquiry learning in her teaching practice. By adopting inquiry learning, Sara wants to introduce her students to the process of conducting inquiries that enable them to engage actively with questions and problems associated with their subject matter. In particular, Sara assigns an inquiry project to students in terms of investigating the DNA structure while encompassing relevant themes such as duplications, mutations, and molecules like nucleotides. Students are participating in an inquiry quest, individually and collaboratively, and often they use digital technology and resources for exploring the knowledge-base actively, critically and creatively. Sara tries to learn more about inquiry-based learning so she engages herself in a WebQuest and finds the ODS/ISE portal. She searches for inquiry activities for schools and she learns that the overarching features for creating a scientific inquiry investigation are: questions, hypothesis, evidence, analyze, explain, connect, communicate and reflect. After familiarizing herself with the essential features of inquiry, Sara wants to find some sort of a model that would provide guidance on the steps and processes that should be considered in designing and implementing an inquiry activity. After reviewing a number of inquiry models Sara decides to use the Orienting and Asking Questions, Hypothesis Generation and Design, Planning and Investigation, Analysis and Interpretation which closely reflects the essential features of inquiry evidenced in the literature. Sara decides to use a blended-learning approach to incorporate the inquiry model where inquiry activities will be enacted both during in-class teaching as well as through the use of technology. 1. Sara decides to use the ISE/ODS portal to design and deliver her inquiry-learning activities based on the four basic inquiry activities: ***Orienting and Asking Questions, Hypothesis generation and Design, Planning and Investigation, Analysis and Interpretation, Conclusion and Evaluation.*** 2. She starts filling the *Orienting and Asking Questions* section by providing an overarching question to
Hypothesis generation and Design	DNA Damage A serious game for learning about DNA		Sara is assigning to students to play the DNA Damage game for helping students to formulate and test their hypothesis and design by using the game. Students will try to identify the necessary DNA links and prevent mutation out of this hypothesis i.e. which links are positive and don't create mutations, students will create their hypothesis.	Each individual student is playing the game and develops his own hypothesis based on the correct DNA pairs while avoiding the mutation rate going high.	

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Planning and Investigation	OSR for searching and retrieving resources	Sara requests from all students to search and retrieve information about DNA structures. Sara suggests to students to visit the OSR portal and try to search for relevant resources that describe DNA duplications and mutations.	In groups of three students are prompted to visit OSR in order to discover resources that describe DNA structures. Each group then prepare a review describing their searching strategy for using ODS as well as what they have investigated.	Each student is assigned to search a different aspect on DNA structures (e.g. mutation, duplication, nucleotides etc.) and try to find and retrieve content on OSR. The student reports his searching strategy and how he did go with his investigation.	students to answer along with relevant resources for them to explore. Sara also is providing a drop down menu with different inquiry questions created by her, for students to choose from. Furthermore Sara is providing an empty space for students to pose their own scientific questions. 3. Then Sara moves on to the next inquiry activity, *Hypothesis generation and design* where she is providing a hypothesis for students to start a scientific investigation, provides a selection of different hypothesis for students to select on, or leaves an empty space for students to create and choose their own hypothesis. To help students to formulate a hypothesis, Sara provides a link of the serious game DNA damage. 4. Then, she continues with the *Planning and Investigation* by trying to give students evidence/data, materials and resources for their investigation, also provides links with different resources and data for students to select from, or she is letting the student to decide how to plan the investigation. 5. In the *Analysis and Interpretation*, Sara is telling students how to analyse evidence through providing resources and drafting guidelines on methods of analysis and also provides a way to interpret explanation via a structured template. Alternatively, Sara also includes online links and drop-down menus, different ways for students to analyse data and finding possible ways to interpret data. Also Sara leaves space for the student to decide how to analyse and interpret data. 6. Finally, in the *Conclusion and Evaluation* activity, Sara is given all the steps required for students to justify their data and conclude explanations. Sara also gives some broad guidelines on how to justify and conclude explanations and an empty space for students to choose how to justify and conclude their explanations. 7. After the Conclusion and Evaluation activity, Sara engages students in a *reflective* process where Sara gives a structured framework for reflection by
Analysis and Interpretation	SurveyMonkey		Students in groups select from possible ways provided by teacher to create a survey highlighting the number of successful DNA pairs as well as the number of mutations created by unsuccessful links. Students then need to analyze and interpret their findings through scientific charts and diagrams generated via the SurveyMonkey tool.	Each student uses SurveyMonkey to analyze the different DNA structures and then is interpreting the analysis through the generation of quantitative charts and diagrams. Sara tells students how to use the tools and what type of analysis she wants students to use.	
Conclusion and Evaluation	Google Docs		Sara provides broad guidelines for each student group to write their evaluations and conclusions to their Google Doc document for the rest of the groups to give feedback on each other. Google Docs allows groups to communicate their	Individual students are drafting their contributions on Google Docs. Sara provides all the steps to proceed to conclusions and evaluations.	

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
			findings to the rest of the class and also getting involved in a reflective process through refining and clarifying their inquiry.		students involving encountering difficulties, likes and dislikes, ways of improvement and actions needed for students in order to improve; Sara also gives some broad guidelines for them to reflect in the form of themes and sub-themes. Sara also leaves space for students independently to write their reflections on the inquiry ptheir learning. 8. In order for other biology teachers to re-use or repurpose Sara's inquiry design, Sara jots down some metadata such as a description, field, keywords, educational objectives (i.e., title, processes and knowledge) and then she saves and submits her inquiry scenario to the system.

1.5 Inquiry-based tool-supported teaching narrative provided by Consiglio Nazionale Delle Ricerche (1st narrative)

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Google Search Stellarium	**Is the Moon really larger when you see it on the horizon?** Discuss individual findings from naked eye observations, web quest and use of Stellarium.		Observe a full moon and make sketches. Search for and collect pictures and/or paintings of full moon on the Web. Use Stellarium to observe a full moon from raise to set.	Mario is a middle school science teacher who wants to motivate students' interest in Astronomy by letting them use a remote telescope. Mario is looking for a challenge that is likely to raise a debate since students will express different predictions. Mario will help the students in making observations and finding the answer to the challenge by coordinating classroom discussions on their predictions, plans for observations and argumentation on their results. He uses the ISE repository tools to find a remote telescope to use and ideas for his lesson plan. The Las Cumbres Observatory Global Telescope is the remote lab he selects. He has found an interesting Astronomy activity (Is the Moon really larger when you see it on the horizon?) on the UniSchooLabs repository. The activity was developed at Harvard-Smithsonian Center for Astrophysics In the MicroObservatory project. After checking the UniSchooLabs remix, Mario has downloaded the teacher's and student's guide of the original version. Mario uses the ISE authoring tool to make his own remix following the Inquiry template provided: ***Orienting and Asking questions***, ***Hypothesis generation and Design***, ***Planning and Investigation***, ***Analysis and Interpretation,*** and ***Conclusion and Evaluation***. • ***Orienting and Asking questions –*** Mario introduces the challenge "Is the Moon really larger when you see it on the horizon?" and ask the students to observe the moon and make observations. Looking at the Moon, with naked eye or telescope, is important. Nowadays we seldom observe the sky. Observing the phenomenon on a simulated sky and conducting a web quest can be useful as well. Note that the reasons of perceptual illusions are beyond the scope of this lesson. • ***Hypothesis generation and Design –*** On the basis of their observation, students are assigned to work in groups to make predictions and use the remote telescope to conduct the experiment. • ***Planning and Investigation –*** The remote telescope is
Hypothesis generation and Design		Class discussion on groups' predictions.	Each group will discuss and make predictions. The group's report is written on the prediction template provided by the teacher.		
Planning and Investigation	Las Cumbres Observatory Global Telescope Stellarium SalsaJ		Each group will plan the observations (they might use Stellarium as a quick simulator of the moon as seen at the telescope site) and record their decision in the planning template. Use the remote telescope to observe the moon, and the SalsaJ software to process the picture downloaded from the remote lab. Measure the diameter of the		

			moon images. Write a report on the findings on the template provided by the teacher.		used to observe the moon and take picture in batch mode. Students have to calculate when the observation should take place and check the weather forecast for a clear sky. While using the remote telescope is fun and dealing with the possible difficulties of getting a good observation is an excellent learning experience. It might be useful to collect a library of full moon telescope images, just in case we run short of time in the class. • ***Analysis and Interpretation –*** Producing comparable measurements of the moon's telescope images is dependent on following a common protocol. This can be a good learning opportunity on measures, instruments' precisions, and experimental errors (teacher guidance is crucial to avoid impasse). An Earth globe might be useful to reason on the distance of the moon from the point of observation (near the horizon and directly overhead). • ***Conclusion and Evaluation –*** The teacher will conduct a classroom discussion to reach a conclusion on the results of the Moon observation. Argumentation is an important phase of reflecting on the hands-on activities. The activity is completed by writing a group report.
Analysis and Interpretation		Group discussion on the data collected. Compare the observation with the prediction. Find an explanation for the results.			
Conclusion and Evaluation			Write a report with the group findings, presenting and justifying its proposed explanations and the final conclusion reached in the class discussion.		

1.6 Inquiry-based tool-supported teaching narrative provided by Consiglio Nazionale Delle Ricerche (2nd narrative)

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	smartphone Logger Pro Tracker	Video analysis and classroom discussion of the various motions. How air friction affects the motion of a falling object?		Shoot a short video of moving objects	Paola is a physics lecturer for pre-service primary teachers. She's preparing a lesson plan on how objects free fall. Paola wants her students to set up experiments for measuring positions and velocities of falling objects. She aims also at letting her students building computational models of their motion. Her students' math knowledge doesn't include calculus, so she will introduce them to a microworld where they can model free fall by building interactive dynamic program in the Logo tradition (see Sherin, B. (2001). A comparison of programming languages and algebraic notation as expressive languages for physics. *International Journal of Computers for Mathematics Learning: 6, 1-61*.) Paola uses the ISE tools to search for lab ideas on free fall. She finds two experiments that use a motion detector (ball toss and air resistance) in the Physics with Vernier collection. A couple of tools to analyze video of moving objects (Logger Pro and Tracker). Finally she has published on the Scratch repository the Tick Model of free fall so that can be used and remixed to model a ball toss and/or free fall with air resistance. Paola uses the ISE authoring tool to make her own remix following the Inquiry template provided: ***Orienting and Asking questions***, ***Hypothesis generation and Design***, ***Planning and Investigation***, ***Analysis and Interpretation,*** and ***Conclusion and Evaluation***. • ***Orienting and Asking questions*** – Students are introduced to the study of motion trough computer analysis of digital video. At 30 frames per second, digital video provides a good set of data for observing the trajectory of objects tossed, dropped, thrown. The video also provides info for calculating the object position in each frame. The widespread availability of smart phones should facilitate the collection of videos from the student. The teacher introduces the task of investigating free fall ignoring or taking into account air resistance. • ***Hypothesis generation and Design*** – In this phase the
Hypothesis generation and Design		Classroom discussion based on group's reports.	Group discussion on how to model and make predictions of free fall without and with air friction. Write a report on the template provided by the teacher		
Planning and Investigation	Go!Motion Logger Pro Tick model		Plan and conduct experiments of free falling objects using the Go!Motion sensor. Collect and present the data using the Logger Pro software. Use and modify the Tick Model to construct a computational model of the observed motion. Write a report on the findings using the template provided by the teacher.		
Analysis and Interpretation		Group discussion on the experiments.			

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
		Compare the observations with the computational models. Find an explanation for the results.			teacher is guiding the students in focusing on the relation of the shape of the objects and the rate of speed at which they fall. Parachutes slow down the fall. Somebody might come up with the hypothesis of a terminal velocity, i.e., reaching a constant speed during the fall. • ***Planning and Investigation*** – Use the Go!Motion sensor to experiment with free fall. With teacher guidance the experiments can be more in the hands of the students; i.e. we should avoid just following recipes. In some lab handbooks running the experiment is reduced to loading a configuration file, reproducing the experimental settings, and clicking a button. The data analysis is automatically done as well. Proper guidance can provide a safety net without removing learner's agency in conducting the experiment. The same advice apply to guiding the construction of the computational models of the free fall. • ***Analysis and Interpretation*** – Experiments of free fall with increasing speed-up and objects reaching terminal velocity in the case of non negligible air friction are analyzed. The experiment are compared and interpreted in the light of the computational models of free fall built. • ***Conclusion and Evaluation*** – After a classroom discussion and presentation of the Physics explanation of free fall by the teacher, the students write, in group, a report of their experiments.
Conclusion and Evaluation			Write a report with the group findings, presenting and justifying its proposed explanations and the final conclusion reached in the class discussion.		

1.7 Inquiry-based tool-supported teaching narrative provided by Nucleo Interactivo De Astronomia

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Stellarium	The whole class reviews or is introduced to the scientific method in all its steps and how the science community agrees on science results. Some history on how astronomy as a science came to be. The whole class discuss the credibility of Astronomy x Astrology and what they think are the main differences.		Each student will use Stellarium to verify the position of the Sun when they were born and compare the astronomical zodiac constellation to the astrological zodiac sign.	Leonor is a physics teacher and wants to promote an inquiry activity to clarify her 7th grade students about science accuracy and the scientific method. She chooses the very appealing topic of Astrology and wants to engage students in thinking critically on the differences and similarities of Astrology and Astronomy and guide them to the conclusion that only the latest is a science. She knows that as a byproduct of her idea will be the improvement of several key skills: critical thinking, communication and presentation, data acquisition and analysis, hypothesis formulation and testing, engage in discussions and accept others opinions and ideas.
Hypothesis generation and Design	ISE inquiry cycle tool		Students will create their own hypothesis about “Astrology as a Science” and design their project on how they will collect evidence to support their claim.		1. Leonor finds a very good planetarium software in the ODS/ISE repository, Stellarium, and an excellent learning activity with the basic instructions on how to explore the zodiacal ASTRONOMICAL constellations. 2. Leonor will reproduce the steps of scientific thought using the 5 steps ISE inquiry cycle: ***Orienting and Asking questions***, ***Hypothesis generation and Design***, ***Planning and Investigation***, and ***Conclusion and Evaluation***.
Planning and Investigation	Stellarium and newspapers		Students will establish a plan for retrieval of information using Stellarium, newspapers or other means in order to acquire data to support their hypothesis.	Along the whole process students are required to gather newspaper and/or other media sources prediction for their astrological zodiacal sign.	3. Leonor starts the ***Orienting and Asking questions*** phase by promoting a discussion on the topic to be addressed, provoking their curiosity with some orienting questions and engaging them with the wish to solve the riddle: is ASTROLOGY a science? Students are introduced to Stellarium and perform some basic tasks to understand how the program works and how they can acquire information from it. 4. During ***Hypothesis generation and Design*** students have to clearly state their ideas and devise a way to prove their arguments. 5. In the ***Planning and Investigation*** Leonor will guide them and suggest how they can retrieve enough information to make statistically correct assumptions, how they can use Stellarium to
Analysis and Interpretation	Stellarium Google Docs		Students should now perform an	Students should compare the astrological prediction of different sources for the	

	spreadsheets		analysis of the acquired data comparing information from the different sources and discussing in groups the relevance of the information and the scientific relevance of it. Students have at this stage to match the astrological maps with the astronomical maps. The acquired data should be analyzed and compared.	same days and find similarities and differences for the prediction for different signs.	reinforce their arguments. 6. Using Stellarium and a google spreadsheet they are now capable of reaching conclusions and Leonor will help them understand why their data favors Astronomy as a Science and Astrology is simply a divinatory art, as trustable as any other. 7. The final step will be the ***Conclusion and Evaluation*** . By this time students will have processed documentation individually and in groups, will have reached their own conclusions and are now capable of presenting it to others and engage in fruitful discussions about the correctness of each other's arguments. 8. Leonor revisits all the process with the class introducing important concepts related to the movement of objects in the sky and how our understanding of this was incorporated in our daily lives.
Conclusion and Evaluation	ISE inquiry cycle tool	Data acquired by the different groups should now be compared and the class as a whole will be driven to provide arguments following the scientific procedure. To accept their peers reasoning and reach a conclusion based in facts and their understanding of them. The critical thinking skills of the students will be greatly enhanced with this activity and during the discussion and result presentation phase the teacher will be able to evaluate the impact on the students' path.			

1.8 Inquiry-based tool-supported teaching narrative provided by Humboldt-Universität zu Berlin

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	"Virtual Lab"	Hans introduces the problem to the class and encourages the students to find a possible solution. He introduces the computer program "virtual lab" which the students can use to train their competencies on problem solving.	The group members can collect as many information about the problem as possible. This contains information about chemicals as well as information about chemical principals or strategies.	Each group member can find information about the problem within the "Virtual Lab" or on the internet.	Hans is a chemistry teacher in a secondary school. As an alternative for his students` regular teaching lessons, he wants to create an inquiry-based learning opportunity. For his 12^{th} grade he chooses the problem of unidentified chemicals, which have to be labeled again. Every formed group has an identical bunch of chemicals. What is known is a list of chemicals that could be possible in this bunch. The students have to learn some methods how organic chemicals can be identified and have to use this freely to solve the problem. Hans wants to provide a possibility to solve the problems of unlabeled chemicals in an eLearning platform, before the group analyses the real chemicals. The main reason is, he hasn't got the equipment to provide every group full excess to the analytical equipment, so the students have to fill their gap of knowledge for analytical methods by themselves and can train the methods within the virtual lab. After their training they had to decide which test they want to do with their unidentified chemicals of the group, as every group has limited access to the equipment or have to share it. Because of that, the students have to plan a distinct problem solving strategy, to identify their chemicals in as few steps as possible. In this case, some carbon acids and alcohol can be analyzed through IR-analysis and through esterification. After the measurements are made, the groups have to combine their information. Since the information are not sufficient enough to solve the problem, the students have to reconstruct their working plan and work on. In the end, every group present their labeled chemicals, and provide the analytical way.
Hypothesis generation and Design	"Virtual Lab"		Each group can formulate a strategy to solve the problem and generates a research plan, taking into account the allocated chemicals.	Every student can use the "Virtual Lab" to evaluate the possible outcomes of his research plan.	
Planning and Investigation	"Virtual Lab"		The students have to decide which chemical substances they want to have measured, which principles they want to follow to maximize the output and what information they can get through the esterification with others. As a matter of fact, the group has to reconfigure the research plan.		
Analysis and Interpretation	"Virtual Lab"		The group has to interpret their results. They have to check whether they have synthesized the correct substance and if they have reached a sufficient output.		
Conclusion and Evaluation		Every group presents their strategy for synthesizing the chemical compound and how to maximize the output. The class discusses the advantages and disadvantages of the different methods.	The other groups compare the proposed method with their own procedure.		

1.9 Inquiry-based tool-supported teaching narrative provided by MENON Network

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	video wiki	Nikos presents the theme and provokes the discussion and the working questions. The whole class discusses the theme.	Students are divided into groups and choose different working questions.		Nikos is a physics teacher and wants to create an inquiry activity presenting the Large Hadron Collider and the work done in CERN. His focus is the different theories of particle physics and he's working with his upper secondary students. In his activities he is collaborating with the ICT teacher. **Orienting and Asking questions** He starts with the video "From the Big Bang to the LHC" which he has already downloaded on his computer. The video is used as the basis of the discussion and for setting the working questions. **Hypothesis generation and Design** Nikos presents the working process and presents the tools to be used. He has already prepared a wiki with some basic information and divides the students in working groups. The students will have to search for information on the different aspects of research done with the Large Hadron Collider. They search the internet to gather the necessary information. They upload the information on the wiki and present it to the rest of the class. **Planning and Investigation** Again in groups, they work with the LHC game on the three distinct categories: "accelerating", "bending" and "focusing". After the first round of experimentation, they present their findings to the other groups and change roles. In this way, all groups work in all "categories" and can compare their results. **Analysis and Interpretation** The students analyze their results and present it to the rest of the class. They compare their findings and check any inconsistencies. **Conclusion and Evaluation** The students are then again divided in groups and work on the class wiki in order to present the theme and the theories of particle physics in a manner that will be understood by their peers in other classes. By presenting the theme, Nikos can check the degree of their understanding of the different
Hypothesis generation and Design	Google LHC game		Each group searches the internet for information and chooses their working questions. The questions and working hypothesis are written on the class wiki and the students start designing their work.		
Planning and Investigation	LHC game		The groups decide on the categories and test with which they'll work on the LHC game and start experimenting. They change roles so as all groups work in different "posts".		
Analysis and Interpretation	LHC game	Data acquired by the different groups is compared and the class as a whole will be driven to provide arguments following the scientific procedure.	The students analyze their results and present it to the rest of the class. They compare their findings and check any inconsistencies.		
Conclusion and Evaluation	wiki	The whole class discuss on the activities and through meta-cognitive reasoning initiated by the	The students discuss on the findings and work on the wiki in order to complete it. They discuss on what and how can be presented to other classes		

learning activity	**tool**	**teaching & learning activities specified by instructional setting**			**narrative**
		whole class	small groups	individually	
		teacher evaluate their acquired knowledge and skills.	with different interests and knowledge.		aspects of the theme but he is also able to discuss the issue of how complicated theories and matters can and should be introduced to wider audiences.

1.10 Inquiry-based tool-supported teaching narrative provided by VELTI

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Interactive Human Body Google Docs	Peter presents an online video animation visualizing the human vital organs and their placement in the body.	Students are divided into small groups. For each group an internal organ is assigned, where Peter has already prepared some basic inquiries that would steer the scientific investigations. Specifically, for each organ its relation and dependency with others is requested, along with the most critical impacting factors. Those questions are given in a Google Document, where students can add more.	After the video demonstration, using the *Interactive Human Body* tool each student is asked to properly position all internal organs to their proper position exploiting the knowledge acquired through the video. The tool also provides interesting facts about each body part enriching the students learning.	Peter, a high-school teacher, wants to organize an engaging and collaborative activity towards raising the awareness of his students on the human anatomy, placing emphasis on the internal organs placement and especially on their functions, dependencies and important factors that drive their operation. Learners should explore the human body, learn about the internal organs and cooperate towards identifying risks and symptoms that could cause their malfunction. Peter searches the ISE/ODS repository and finds several interesting scenario descriptions and tools that are capable of assisting him in designing the lesson flow, activity and exercises, exploiting the inquiry-based learning methodology. Focusing both on technology and in class learning Peter makes use of a blended, collective inquiry scenario, consisting of four basic activities: Orienting and Asking questions, Hypothesis generation and Design, Planning and Investigation, and Conclusion and Evaluation. **1. Orienting and Asking questions** Peter begins by presenting to the class an online 3D video animation visualizing the human organs and their basic characteristics. Afterwards he points out the importance of each organ in the human body and splits the students into groups, each one associated with one human organ. He also provides a list of questions that each group has to look for and answer. **2. Hypothesis generation and Design** Afterwards, Peter asks the students to think of and propose various hypothesis that would steer their research. He also provides some examples to guide the students on their hypothesis. **3. Planning and Investigation** The teacher provides the students a list of references (literature, electronic tools, video, etc) they can use towards performing their
Hypothesis generation and Design	XMind Google Docs		Each group now focuses on setting valid hypotheses that would allow the concrete definition of the problem and set the investigation goals. Using Google Docs Peter sets some basic hypotheses, like "Consider that the human body is dehydrated. What is the impact on the liver?" Such hypotheses is documented using Google Docs, while using XMind to be scoped in more detail through brainstorming on mind maps.		
Planning and Investigation	Khan Academy Google Docs XMind		Peter prompts the students to work closely together and start devising responsibilities amongst the group. Khan academy is a great start for understanding how various internal organs work. Groups can again create mind maps to associate different organs' interconnections (via the use of XMind). An initial collection, in terms of Mind Map components has already been created by Peter in Google Docs. Peters asks the students to constantly update their Google Doc with their		

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
			current progress, so that all can always monitor their status.		investigation. He also instructs the students to keep him actively involved towards monitoring their status and progress.
Analysis and Interpretation	Google Docs Google Scholar		Each group documents its findings in Google Docs highlighting their main goals and achievements. Peter electronically collects each group report, evaluating it and providing reasonable interpretations on the groups inquiries. Google Scholar is used by Peter to make sure that his interpretations are valid and correct.		**4. Analysis and Interpretation** Initially Peter prompts the students to propose their own interpretation of the data and results they acquired during their investigation. Afterwards he collects their proposals and thoughts and provides accurate interpretations based on a set of links and references he also provides to the students.
Conclusion and Evaluation	WordWall Google Docs LimeSurvey		Peter asks for each group to create a presentation using Google Docs towards presenting to the rest of their classmates their findings. Moreover he asks from each group to create a small mind-teasing game using WordWall towards engaging and attracting more students.	After all presentations the students are requested to vote for the best presentations using a LimeSurvey campaign. Moreover, their thoughts and open questions are also documented providing input for a next class.	**5. Conclusion and Evaluation** Peter collects the results and conclusions of all groups and organizes a presentation session where all groups present to the others their work. This activity raises open questions and thoughts, which in various occasions necessitate the student groups to perform extra analysis and investigation in line with Steps 3 and 4. Finally when all questions are solved and the outcome is considered acceptable, Peter asks the students to vote for the best presentation, encouraging competiveness.

1.11 Inquiry-based tool-supported teaching narrative provided by Croatian Academic and Research Network

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Wiki	Collaborative work in wiki creating documents. Students search for resources and create pages about gravity force.	Teacher will form three groups of students. Each group will have their own wiki page on which they will post questions.	Each student has to actively contribute to wiki creation. They have to think about gravity force and try to post at least one question.	The main objective of this lesson is to learn all important issues related to gravity force. The teacher has to create activities that will support active participation of students through five main stages of the lesson. They begin with orientation and asking questions about the problem, then proceed with generating hypothesis, planning and investigation, the next step is analysis and interpretation and finally making conclusions and evaluation of their work. The paradigm on which teachers will rely during the design of the lesson is inquiry-based learning. Inquiry-based learning describes approaches to learning that are based on the investigation of questions, scenarios or problems - often assisted by a facilitator. Inquirers will identify and research issues and questions to develop their knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research. In implementation of inquiry-based learning into lesson teacher will use various tools. Each phase of the lesson will be achieved by using an appropriate tool. Students will use these tools as a whole class, in the small groups or as individuals.
Hypothesis generation and Design	Lesson Gravity force from The "Nikola Tesla" National Distance - Learning Portal	Teacher presents the lesson on a smartboard.	Students will discuss the lesson in small groups. Conclusions of each group will be presented in front of the whole class.	Every student individually read the lesson about gravity force, try simulation and answers questions in a short test implemented in the lesson.	
Planning and Investigation	Bubbl.us	Students collaboratively create mind map about gravity force.	Teacher will form small groups of students. Each group has the task to propose the way of testing of gravity force.	Each student has to prepare himself for this task. They have to read all relevant resources about gravity and resources which could help them to get an idea for testing the gravity force.	
Analysis and Interpretation	Padlet	After conducting the tests of gravity force in the classroom students have to interpret the results. They will use Padlet to represent and interpret results.	Students will be distributed into three groups. Each group will create their own Padlet board on which they will present the results of testing the gravity force.	Students have to enable themselves in using Padlet. They also have to think about how to present the results of testing.	
Conclusion and Evaluation	Wiki	Students have to make conclusions about this activity and publish it on wiki page.	Each group has to publish conclusion about testing of gravity that they conducted. They have to present the idea, describe the process and present the results.	Each student has to think about all that has been done during the lesson in the whole class and in the small groups. Students should assess the performance of their work and make conclusions.	

1.12 Inquiry-based tool-supported teaching narrative provided by Dublin City University

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Gooru: is a tool for students that offers access to standards-based online resources in teacher organized playlists. Google Docs: Is a tool for teachers and students to pose their questions	The teacher demonstrates to the class how to use Gooru and give them the student pin to access their Classpage	Students are divided into groups of 4. Each group access their own Google Doc to decide the questions they are going to select or they can formulate their own and write it into the Google Doc. Broadly focused questions are used by the teacher allowing them to decide what they should look for on their own and narrow focused questions to help them recognize details that they might miss.	Students will access a designated class web page that was created with a class code. The web page will allow students to view videos and simulations on density, mass and volume that were preselected. The class page will also include a quiz to guide students through new concepts.	Marian, a Junior Science teacher, uses a guided-inquiry method to facilitate the learning experience and structures the inquiry around specific goals of instruction. Marian wants her students to construct understanding by learning through their experiences and their own questions whilst she mediate the process. The aim of the lesson: to get students to investigate; why density is a characteristic property of a substance? **1. Orienting and Asking questions** Marian starts the lesson by stimulating the curiosity of her first year junior science student by giving an introduction related to concepts that have to be acquired. She also engage her students in a conversation about what they already know about the concepts of mass, volume, density and their relationship. She helps build understanding by asking guided questions that can be answered with resources at their disposal. She then guides them towards the resources to find the information about mass, volume and density. She uses class discussion and guided questioning throughout the information searching process. As her students develop their understanding of scientific inquiry, she encourages them to generate their own testable questions.
Hypothesis generation and Design	Socrative: Is a student response system ideal for interaction within classroom.		The group will access the simulations on density with their class code. They will test their hypothesis.	Each student takes part in a quiz. This allows the teacher to be able to visualize and measure student understanding in real time.	**2. Hypothesis generation and Design** The results from the quiz allow her to study her students' evolving understanding, assess what path they are on and help them to take advantage of opportunities that enable them to construct new and more sophisticated understandings.
Planning and Investigation	Gizmos is an interactive simulation that makes key concepts easier to understand and fun to learn for students.		The group will access the simulations on density with their class code. They will test their hypothesis by using the student's exploration sheets and complete the assessment questions. All of these will be saved to examine later.	Each student will complete the Student Lab Investigation sheet.	**3. Planning and Investigation** Once each group is confident and clear on their formulated hypotheses, she then proceeds to ask each group to formulate and conduct their own scientific investigations. The students determine both processes and solutions. This will help the students develop specific investigation skills and a better understanding of science concepts. The students lead the guided inquiry process as they reach self-formulated conclusions through their investigation. During the investigation she addresses the whole class and individuals. However, during their investigations, she asks action questions that get students to think and respond at

	Google Docs: Is a tool for teachers and students to pose their questions.				higher cognitive levels. She also guides them through questions if they are distracted by the investigation. She uses questions to keep them focused on their experiment and guide them over any obstacles. If required, she approaches her students individually to draw attention and discuss the status of their investigation, prompting more precise attempts for student to gather more data.
Analysis and Interpretation	Google Docs: Is a tool for teachers Gooru: is a tool for students that offers access to standards-based online resources in teacher organized playlists.		The groups reform to exam each other's exploration sheet and Student Lab Investigation sheet to analyze the evidence of the investigation.	Students using their assigned pin access this learning search engine to find an example where density is used by scientist or any discipline in real life.	**4. Analysis and Interpretation** The groups are reformed in this phase. Students will feel more comfortable in groups as they can exploit each other's skills while providing social support and observing the contributions of each member. Students naturally seek out others to help them to solve problems and perform tasks. Each group will be guided in the process of organizing their data and analyzing their evidence by providing appropriate resources and guidelines. The teacher engages in discussion with the groups on how to interpret their data. If the groups are not happy with their results or are not clear in the solution then they can revisit the planning and investigation stage. If some groups want to investigate a new inquiry they can also return to the previous phase. They can move back and forth between phases so that new skills and understandings can be obtained. Students are asked to take their expertise and apply it to an everyday example. The idea of this exercise is when students actively seek connections in their learning; they are not likely to remember what they have learned.
Conclusion and Evaluation	Google Docs: Is a tool for teachers and students to pose their questions.			Students access their Student Lab Investigation sheet. The completed Student Lab Conclusion sheet will help students to identify ways in which substances differ in mass, volume, and density. They will use the data chart to conclude that density is a characteristic property of a substance. They will also understand the relationship between density and floatation. Each student will fill in a Student Questions for post-phase reflection.	**5. Conclusion and Evaluation** After students have finished the investigation and examined their lab sheets, the teacher brings closure to the lesson by bringing them back to their original question. A framework is developed that guides students in justifying their data and conclusion. Students are encouraged to reflect on the processes and decisions that were entailed by the process so that they understand more. This also involves thinking again about the initial question, the path taken and the actual conclusions.

1.13 Inquiry-based tool-supported teaching narrative provided by Ellinogermaniki Agogi

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Natural Europe: Renewable, Green, Clean? Wind Energy and Solar Energy	Sophia, prior to any discussion, shows to her students a photo of a traditional energy plant, and asks them to describe it. Following this, Sophia asks her students a set of questions on non-renewable and renewable energy sources.			Sophia is a natural sciences teacher in primary education, with a special interest in renewable energy resources. In order to sensitize her students accordingly, Sophia uses inquiry-based methods and a serious game, as well as field trips, to help the students understand and familiarize themselves with the concepts introduced. More specifically, Sophia engages students in a set of inquiry-based exercises, simple and more advanced investigation and activities to propose hypotheses, to consider alternative explanations and formulate final ideas, to help them adopt a leading role in the learning process and reach a scientifically-based conclusion. Students are expected to participate on an individual level and as part of teams, to complete the different activities. Technology-based tools and online platforms are to be made available to the students, in order to explore how well-established is their knowledge. Through the ODS/ISE portal, Sophia comes across ready-to-use inquiry-based learning scenarios created by teachers, museum educators and scientists, that are easily applicable and adaptable to her needs. In order to proceed with the implementation of her learning scenario, Sophia decides to follow these five steps: ***Orienting and Asking Questions:*** After provoking the students' curiosity, Sophia presents her students a set of scientifically oriented questions to further enhance their engagement in thinking about the target subject matter based on their existing knowledge. ***Hypothesis generation and Design:*** Sophia encourages her students to propose possible explanations to the questions emerged from
Hypothesis generation and Design	Natural Europe: Renewable, Green, Clean? Wind Energy and Solar Energy	In order to pinpoint and confront possible misconceptions of her students, and to lead them to propose possible explanations to the questions raised from the previous activity, Sophia poses certain questions to the whole class concerning specific sources of renewable energy. By discussing the most and least popular myths and truths, Sophia aims to help her students overcome the misunderstandings and to build a strong base to discuss the matter within their			

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
		teams in the next steps.			the previous step, in order to identify possible misconceptions in her students' thinking. For this and the following activities, the students are expected to work in groups. ***Planning and Investigation:*** Sophia divides this step in two sub-phases, the first of which is to take place in the classroom, and the second one is programmed to take place whether physically or virtually outside the classroom, in a museum. For the first sub-phase, Sophia guides her students to answer the questions emerging from the previous steps by looking for the material of her choice, retrievable also through the ODS portal, to help them find evidence in order to answer scientific questions. For the second phase, the students are guided to use the chosen material while engaging in experimentation with the exhibits of interest and thus further enhance their answers and knowledge. In this sub-phase, the students can also access an online game focusing on renewable energy sources. ***Analysis and Interpretation:*** Sophia asks her students to form and orally communicate their explanations to their peers on the given subjects. Following this, Sophia asks them to consider alternative potential explanations reflecting scientific understanding. ***Conclusion and Evaluation***: Upon return to class, Sophia facilitates her students to form a final presentation based on their findings of every phase, to present and justify their proposed explanations to other groups. Discussion may follow; as well as other activities that will help the students evaluate their process and outcomes.
Planning and Investigation	Natural Europe: Renewable, Green, Clean? Wind Energy and Solar Energy		Sophia divides the class in four small groups (two occupied with solar energy and two occupied with wind energy). After assigning them their subjects, Sophia asks them to come up with some initial results in two days, in order to create a cardboard with the information discovered, and their thoughts, which they will enrich during the visit to the museum. During their visit, the students are expected to complete the following tasks with their groups: • seek information in the space to enrich the content of their boards. • use a cell phone with Internet connection to play an online energy-related game.		
Analysis and Interpretation	http://natural-europe.fit.fraunhofer.de/naturalEurope/games/MuseumGamePlayer.apk Renewable, Green, Clean? Wind Energy and Solar Energy		The students are asked to work with their groups to come to a conclusion on their assigned questions, based on the information collected. Then, Sophia initiates a discussion on the possible existence of a more efficient energy form than wind or solar energy. Such an example could be the nuclear energy. Student groups are asked to examine the other options and come to a conclusion.		
Conclusion and Evaluation	Natural Europe: Renewable, Green, Clean? Wind Energy and Solar Energy	Then, the students under Sophia's guidance will discuss and vote the energy source that they consider better.	Based on the research findings, the teams are expected to complete and perfect their presentation cardboards, and present them to the rest of the class.		

1.14 Inquiry-based tool-supported teaching narrative provided by University of Helsinki

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
Orienting and Asking questions	Shooting Stars: http://www.daretothinktheimpossible.com/shootingstars/			Each pupil makes a concept map about solar system. Students should investigate and become familiar with Kepler's laws, Newton's theory of gravitation, motion in gravitational field, three body problem and super computers before they start to play.	Shooting Stars is a computer game. The basic principle is rather simple. The purpose of the game is to create planets, which will orbit one or even several stars trying to not collide with stars, other planets or moons. In the game there are several levels. The player cannot influence on the "starting point" of the planet's orbit. Only on the velocity. That is both magnitude and direction. The program shows the beginning of the planet's orbit concerning every starting velocity. It helps the player to plan such orbits, that the planets do not collide. Even the program is a game, it has a physical background. It is motion in gravitational field. It is an old physical problem, first solved by Kepler. In astronomy, Kepler's laws of planetary motion are three scientific laws describing orbital motion, originally formulated to describe the motion of planets around the Sun. Kepler's laws are: The orbit of every planet is an ellipse with the Sun at one of the two foci. A line joining a planet and the Sun sweeps out equal areas during equal intervals of time. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit. Johannes Kepler published his first two laws in 1609, having found them by analyzing the astronomical observations of Tycho Brahe. Kepler discovered his third law many years later, and it was published in 1619. At the time, Kepler's laws were radical claims; the prevailing belief (particularly in epicycle-based theories) was that orbits were perfect circles. Most of the planetary orbits can be rather closely approximated as circles, so it is not immediately evident that the orbits are ellipses. Detailed calculations for the orbit of the planet Mars first indicated to Kepler its elliptical shape, and he inferred that other heavenly bodies, including those farther away from the Sun, have elliptical orbits too. Kepler's laws and his analysis of the observations on which they were based challenged the long-accepted geocentric models of Aristotle and Ptolemy, and generally supported the heliocentric theory of Nicolaus Copernicus (although Kepler's ellipses likewise did away with Copernicus's circular orbits and epicycles), by asserting that the Earth orbited the Sun, proving that the planets' speeds varied, and using elliptical orbits rather than circular orbits with epicycles. Some eight decades later, Isaac Newton proved that relationships like Kepler's would
Hypothesis generation and Design				Good sources of theories can be found in the following sites. http://en.wikipedia.org/wiki/Gravitation http://www.physicsclassroom.com/class/circles/u6l4a.cfm http://en.wikipedia.org/wiki/Ellipse http://www.physicsforums.com/showthread.php?t=586069 http://en.wikipedia.org/wiki/Three-body_problem http://en.wikipedia.org/wiki/Supercomputer	
Planning and Investigation				Students can use stopwatch and ruler to measure orbiting times and	

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
				radius' of satellites. They can make at least rough calculations about relations between radius and orbiting times. Students are asked to observe the eccentricity of the orbit ellipsis. How the planets move in different ends of the major axis.	apply exactly under certain ideal conditions that are to a good approximation fulfilled in the solar system, as consequences of Newton's own laws of motion and law of universal gravitation. Because of the nonzero planetary masses and resulting perturbations, Kepler's laws apply only approximately and not exactly to the motions in the solar system. Voltaire's Eléments de la philosophie de Newton (Elements of Newton's Philosophy) was in 1738 the first publication to call Kepler's Laws "laws". Together with Newton's mathematical theories, they are part of the foundation of modern astronomy and physics. First level of the game gives a good opportunity to study and verify all three Kepler's laws. A clock and a ruler are useful help tools. In the next levels the physics and especially the mathematics of the motion becomes much more complex. The player is now in front of three-body problem. Three-body problem has two distinguishable meanings in physics and classical mechanics: In its traditional sense, the three-body problem is the problem of taking an initial set of data that specifies the positions, masses and velocities of three bodies for some particular point in time and then determining the motions of the three bodies, in accordance with the laws of classical mechanics (Newton's laws of motion and of universal gravitation). In an extended modern sense, a three-body problem is a class of problems in classical or quantum mechanics that model the motion of three particles. Typically, all three particles are considered as point masses, neglecting their shape and internal structure, and the interaction among them is a scalar potential such as gravity or electromagnetism. Historically, the first specific three-body problem to receive extended study was the one involving the Moon, the Earth and the Sun. The gravitational problem of three bodies in its traditional sense dates in substance from 1687, when Isaac Newton published his 'Principia' (Philosophiæ Naturalis Principia Mathematica). Newton took the first steps in the definition and study of the problem of the movements of three massive bodies subject to their mutually perturbing gravitational attractions. Newton also took the first steps to the lunar theory, the motion of the Moon under the gravitational influence of the Earth and the Sun. During the second quarter of the eighteenth century, the problem of improving the accuracy of the lunar theory came to be of topical interest. The topicality arose mainly because it was perceived that the results should be applicable to navigation, that is, to the development of a method for determining geographical longitude at sea. Following Newton's work, it was appreciated that at least a major part of the problem in lunar theory consisted in evaluating the perturbing effect of the Sun on the motion of the Moon around the Earth.
Analysis and Interpretation				Students should prepare to answer questions like 1. How did the Kepler's laws realized in the program? 2. What is the main difference in motion in gravitational field, when there is only one massive center object + one or more orbiting light satellites compared to the situation, when there is two or more massive objects? 3. How is the need of the calculating power solved on a program? 4. How many different types of forces are present? 5. What are the formulas of the forces?	
Conclusion and Evaluation				Each pupil makes again a concept map. First and last maps are compared with	

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
				each other. If possible, students can show their investigations to the other students. Especially, if they have found something new from motion in gravitational field, which was not familiar before or if something old physical knowledge crystallized to the player during play.	Jean d'Alembert and Alexis Clairaut, who developed a longstanding rivalry, both attempted to analyze the problem in some degree of generality, and by the use of differential equations to be solved by successive approximations. They submitted their competing first analyses to the Académie Royale des Sciences in 1747. It was in connection with these researches, in Paris, in the 1740s, that the name "three-body problem" (Problème des Trois Corps) began to be commonly used. An account published in 1761 by Jean d'Alembert indicates that the name was first used in 1747. In 1887, mathematicians Ernst Bruns and Henri Poincaré showed that there is no general analytical solution for the three-body problem given by algebraic expressions and integrals. The motion of three bodies is generally non-repeating, except in special cases. Three-body problem is more relevant when the close each other moving objects are stars than planets. Situation is then called a star system or a stellar system. That is is a small number of stars which orbit each other, bound by gravitational attraction. A large number of stars bound by gravitation is generally called a star cluster or galaxy, although, broadly speaking, they are also star systems. Star systems are not to be confused with planetary systems, which include planets and similar bodies. A stellar system of two stars is known as a binary star, binary star system or physical double star. If there are no tidal effects, no perturbation from other forces, and no transfer of mass from one star to the other, such a system is stable, and both stars will trace out an elliptical orbit around the center of mass of the system indefinitely. See Two-body problem. Examples of binary systems are Sirius, Procyon and Cygnus X-1, the last of which probably consists of a star and a black hole. A multiple star consists of three or more stars which appear from the Earth to be close to one another in the sky. This may result from the stars being physically close and gravitationally bound to each other, in which case it is a physical-multiple star, or this closeness may be merely apparent, in which case it is an optical-multiple-star. Physical multiple stars are also commonly called multiple stars or multiple star systems. Most multiple star systems are triple stars. Systems with four or more components are less likely to occur. Multiple-star systems are called triple, trinary or ternary if they contain three stars; quadruple or quaternary if they contain four stars; quintuple or quintenary with five stars; sextuple or sextenary with six stars; septuple or septenary with seven stars, and so on. These systems are smaller than open star clusters, which have more complex dynamics and typically have from 100 to 1,000 stars. Most multiple star systems known are triple; for higher multiplicities, the number of known systems with a given multiplicity decreases exponentially with

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	individually	
					multiplicity. For example, in the 1999 revision of Tokovinin's catalog of physical multiple stars, 551 out of the 728 systems described are triple. However, because of selection effects, our knowledge of these statistics is very incomplete. Multiple-star systems can be divided into two main dynamical classes: hierarchical systems which are stable and consist of nested orbits that don't interact much and so each level of the hierarchy can be treated as a Two-body problem, or the trapezia which have unstable strongly interacting orbits and are modeled as an n-body problem, exhibiting chaotic behavior. The three-body problem is a special case of the n-body problem, which describes how n objects will move under one of the physical forces, such as gravity. These problems have a global analytical solution in the form of a convergent power series. Among classical physical systems, the n-body problem usually refers to a galaxy or to a cluster of galaxies; planetary systems, such as star(s), planets, and their satellites, can also be treated as n-body systems. Shooting Stars program demonstrates fine and understandable, how the predictable movement of planets orbiting a massive central body like Sun changes suddenly to an unpredictable and chaotic movement, when objects are added by one. In the program is also a very clever solution to the need of calculation power. It works over the Internet and uses the processing power of super computers. To get more than the pleasure of playing a very addictable game, the student should have some knowledge about gravitation and motion in gravitational field. Therefore the program gives best educational use for students age 16 or over. For instance in Finland topic gravitation is in national curriculum for upper secondary school, and even there for second years students. Summa summarum. The game has fulfilled its educational goals, if the student (player) gets an idea, that one most simple force, which has only one direction, pulling, can cause most complex, unpredictable and chaotic movement even when there are only three bodies attracting each other. Thinking about that can lead someone's mind to the galactic spheres.

1.15 Inquiry-based tool-supported teaching narrative provided by SETApps

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	Individually	
Orienting and Asking questions	F1inSchools Resources: *videos*, *images*, *presentation files* *Case Studies* *F1 in Schools Teachers Guide* *F1inSchools Student Guide*	This activity sets out what students have to do in the *F1 in Schools* challenge. What is the F1 in Schools Design Challenge? How does the F1 in Schools Design Challenge work? How does the F1 in Schools Design Challenge benefit students? The teacher can use media tools (videos, photos, ppt files) to introduce the challenge in the classroom. Here is a sample video showing the	The teacher will decide about how to group students into teams. It is important that the students in each team can work together and that they are reasonably well-matched in ability, since they will each have a different role. Also the teacher should remember that teamwork is not natural to everyone. Be aware that teams will be in competition, and this can produce strong emotions in some students. By deciding upon the teams in advance, teacher can plan a balance between personalities and gender across a class. The teacher can use Case Studies from students taking part in the competition to communicate with members of his/her team to discuss how the F1 in Schools challenge can give them the drive to achieve their goals, to succeed in their life, to get a good job, to meet new people and make new friends. Some F1 in Schools Success Stories can be found here: http://rea.org.au/category/f1-in-schools/success-stories The teacher could discuss about the core activities of the Team Manager to ensure that the team follows the team's vision, that they stick to their proposed timescale and that they keep to their agreed team roles. The students' involvement in the discussions can be monitored.		The F1 in Schools is a worldwide multi-disciplinary challenge for pupils aged from 9-19, and one of the largest educational initiative promoting Science, Technology, Engineering and Mathematics (STEM). It is now in its 14th year of operation and has grown around the world operating now in over 30 countries. The challenge inspires students to use ICT tools to learn about science, physics, mathematics, aerodynamics, design, manufacture, branding, graphics, sponsorship, marketing, leadership/teamwork, media skills and financial strategy, and apply them in a practical, imaginative, competitive and exciting way. Besides using this initiative for teaching Science the formed teams are given the opportunity to compete regionally, nationally and internationally for the F1 in Schools World Championship trophy. F1 in Schools Challenge is not all about speed, competing student teams are also assessed and judged on the quality of their engineering, graphic design, resource management, portfolio, media skills, handling of sponsorship and verbal presentation of their work. The F1 in Schools uses Key Performance Indicators to assess the students in three broad areas: Applied Competence, Critical Thinking, Collaborative and Leadership Competence. A favorite aspect of F1 in Schools is its internationality – no other student project operates in so many countries around the globe and brings together young people from so many different cultures on the same level. F1 in Schools enables two teams from different countries to combine their skills in collaboration and present

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	Individually	
		highlights of F1 in Schools 2012 World Finals: http://www.youtube.com/watch?v=3frL41trwB8			themselves as ONE team to compete with national champions representing their Country at the World Finals. **Mapping inquiry-based process with five teaching and learning activities** **1. Orienting and Asking questions** Teacher starts this section by providing essential and guiding questions to introduce the F1 in Schools challenge and answer what teams are required to do, along with relevant resources for them to explore. **What is the F1 in Schools Design Challenge?** It's a global multi-disciplinary challenge open to teams of students 9 to 19 years old, who use Science, Technology and their imagination to design and manufacture the fastest CO2-powered model race car. Teams race their cars at a regional competition. Winners can go on to compete at a national and worlds competition. Teams are judged on the speed and design of their cars, on oral presentations, and on their "pit" displays. Videos with the best moments of F1 in Schools World and National Finals can be used: http://www.youtube.com/watch?v=3frL41trwB8 http://www.setapps.gr/en/gallery/tv-reports_en http://www.youtube.com/user/F1InSchoolsGreece?feature=watch https://www.dropbox.com/s/hlfzshiiubnzqac/F1%20in%20Schools%20HighlightsH264.mov **How does the F1 in Schools Design**
Hypothesis generation and Design	F1inSchools Recourses: *rules and regulations* *Technical and Competition Regulations*, *Assessment Items* *5 page portfolio*	The activity focusing upon not only what teams are required to do, but also what will help teams to succeed. Asking students to think a team name and decide job roles: Team Manager, Manufacturing Engineer, Design Engineer, Graphic Designer and Recourse Manager. Discussion about the F1 in Schools challenge 6 Key Elements: Plan, Design, Analyze,	The teacher will ask teams to put together a 5 page portfolio documenting their first ideas (first approach) on the project. To help teams on this task a 5 pages Portfolio Samples could be used as a template: http://www.f1inschools.gr/wp-content/uploads/downloads/2013/01/5PagePlans_Team_Quasar.pdf		

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	Individually	
		Make, Test, Race Discussion about the regulations and assessment items of the challenge. Students will need to follow these regulations and judging items. It is worth becoming familiar with the Technical and Competition Regulations, and Assessment Items of the challenge. A summary of the hypotheses and design sessions in the F1 in Schools Challenge can be found in the link below. https://drive.google.com/file/d/0B-			**Challenge work?** **- Form a team:** Students form a team of 3 – 6, develop a name for the team and decide on job roles for the team members: Team Manager, Manufacturing Engineer, Design Engineer, Graphic Designer and Resource Manager. The team then registers with their local F1 in Schools organiser to enter their closest Regional Final event. **- Business and Sponsorship Plan:** Each team must prepare a business plan, develop a budget and raise sponsorship, just as happens in an F1 team. Teams are encouraged to collaborate with industry and create business links. **- Design**: Using 3D CAD (Computer Aided Design) software, the team sets about designing their F1 car of the future to the specifications set by the International Rules Committee, just as the F1 teams design their car to the technical regulations of the sport. **- Analyse:** Aerodynamics are analysed for drag coefficiency in a virtual wind tunnel using CFD (Computational Fluid Dynamics) software. **- Make**: Using 3D CAM (Computer Aided Manufacture) software, the team evaluates the most efficient machining strategy to make the car and transfers their design into a balsa wood model car. **- Test:** Aerodynamics are tested in wind and smoke tunnels to verify the data and research applied earlier in the process. **- Pit Display**: Each team will create an informative display showing their work through each stage of the project and will also develop a team identity, including a logo, clothing, merchandise and print materials.

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	Individually	
		JIGA25ExZ8Zkk0eUlpUmp2Z1k/edit?usp=sharing			- **Scrutineering**: Cars are submitted to Parc Ferme where the judges scrutinize every dimension to check that they comply with the rules and regulations. - **Engineering judging**: Judges meet with each team to find out more about the process and strategy of the car design and manufacture and give the team an opportunity to explain their rationale and methodology used in the development of their F1 in Schools car. - **Verbal presentation**: Each team prepares a presentation to perform to a panel of judges. Each of the team members will take their turn to convey their contribution and all aspects of the challenge are described to the judges, within a set 10 minutes time limit. - **Portfolio Judging**: The teams will put together a 20 page, A3, portfolio documenting their project, covering all elements: design, research, manufacture, testing, business plan, sponsorship activities and finances. - **Race:** Each team will race their car on the bespoke F1 in Schools 20 meters straight. A reaction timing speed is judged as part of the World Finals, in addition to a pure speed test. In addition, a 'knock-out' racing event is held as part of the World Finals. **How does the F1 in Schools Design Challenge benefits students?** The F1 in Schools Design Challenge: • Helps students understand the relationships between science, technology, engineering and math. • Applies advanced technology to real engineering design challenges. • Makes connections across curriculum areas. Students learn about: • Physics • Sponsorship
Planning and Investigation	F1inSchools Recourses: *F1 in Schools Online Curriculum Resource* *computer-aided design (CAD) software*, *computational fluid dynamics (CFD) simulation software*	The teacher can use F1 in Schools Curriculum Resource to support hypotheses that the students should investigate: How does friction affect the speed of the car? What have the car designers done to the wheels to try and minimize drag? If you were a racing driver, e.g. Lewis Hamilton, would you like your car manufacturer, e.g. McLaren, to build you a car with a low mass or a car with a high mass?	Teams start to investigate their ideas and test their hypotheses. Using computer-aided design (CAD) software, as well as computational fluid dynamics (CFD) simulation software, team members collaborate to achieve their goal of producing the fastest model Formula One car. The use of virtual reality wind tunnel software allows the team to test and improve their car's design. **Important Note:** Both CAD and CFD software are provided free of charge to all F1 in Schools teams due to a global partnership with the manufacturers of the software.		

learning activity	tool	teaching & learning activities specified by instructional setting			narrative
		whole class	small groups	Individually	
		The link below provides lesson plan templates that can be used: https://www.dropbox.com/sh/twelj3zqobfcwxn/0MCRui0OZB			• Aerodynamics • Marketing • Design • Leadership and teamwork • Manufacturing • Media skills • Branding • Financial strategy • Graphics • Fosters an interest in engineering, science and technology, manufacturing, marketing and graphics. • Develops job-related "soft skills" as identified by business and industry. • Promotes self-directed, collaborative learning. **2. Hypothesis generation and Design** The teacher can make this activity a class discussion, asking students to think a team name and decide job roles, and focusing upon not only what teams are required to do, but also what will help teams to succeed. **3. Planning and Investigation** The teacher can use F1 in Schools Curriculum Resources to support hypotheses and ideas that the teams need to investigate. **4. Analysis and Interpretation** The teacher can ask students to examine the 20 pages portfolios of teams participated in previous World Finals, and compare with data investigation and solutions found by the students themselves for the same curriculum area. Teacher can support the process by organizing the collected data and interpreting these by identifying key issues and criteria.
Analysis and Interpretation	F1inSchools Recourses: *20pages portfolios templates* *(1)* *20pages portfolios templates* *(2)*		The 20 pages portfolios of the teams participated in previous World Finals can also be examined, and compared with data investigation and solutions found by the students themselves for the same curriculum area. The links below provide 20 pages Portfolio templates: http://www.f1inschools.gr/wp-content/uploads/downloads/2013/01/Portfolio-PentaGliders.pdf http://www.f1inschools.gr/wp-content/uploads/downloads/2013/01/Portfolio-Basilisk-Performance.pdf The teacher can support the process by organizing the data collected and interpreting these by identifying key issues and criteria.		
Conclusion and Evaluation	F1inSchools Recourses: Outcomes F1inSchools web Sites: *F1inSchools Germany*		The teacher will ask teams to evaluate the outcomes of other teams participated in previous World Finals and determine the extent to which these meet the key issues and criteria set in 2.4 activity. The teacher will ask teams to put together their final 20 page portfolio documenting their ideas (final approach) on the project. The teacher can use the assessment		

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	[*F1inSchools UK*](#) [*F1inSchools Ireland*](#) [*F1inSchools Portugal*](#) [*F1inSchools Greece & Cyprus*](#) [*F1inSchools Czech Republic*](#) [*F1inSchools USA*](#) [*F1inSchools Australia*](#) [*F1inSchools UAE*](#)		items (evaluation criteria) specified by the F1 in Schools Regulations to evaluate the outcomes of his/her teams. The teacher could also discuss with the students to identify if any improvement on their 20pages portfolio is possible, and determine whether the learning goals are achieved. The F1 in Schools Score Cards can be found in the link below: https://drive.google.com/file/d/0B-JIGA25ExZ8enlSVEllNEJLaVE/edit?usp=sharing		**5. Conclusion and Evaluation** The teacher will ask teams to evaluate the outcomes of other teams participated in previous World Finals and determine the extent to which these meet the key issues and criteria set in **Analysis and Interpretation** activity. Basically the teacher can switch back and forward between **Planning and Investigation, Analysis and Interpretation** and **Conclusion and Evaluation** until the students are satisfied with the conclusions they can arrive. At certain points the teacher will ask teams to put together their final 20 page portfolio documenting their ideas (final approach) on the project. After collecting the final reports, the teacher can use the assessment items (evaluation criteria) specified by the F1 in Schools Regulations to evaluate the outcomes of his/her teams. The teacher could also discuss with the students to identify if any improvement on their 20 pages portfolio is possible, and determine whether the learning goals are achieved.