Module Booklet for

Storyline Tool

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Table of Contents

Table of Contents 2

Description of the Storyline Tool 3

Background information 3

Link to Coherent Science Instruction 3

Possible Integration into the Teacher Education Curriculum 4

Difficulties of Pre-Service Teachers 4

Evaluation of Pre-Service Teachers’ Storyline 5

Suggested Activities for Introduction 7

Instructor Materials 10

Vignette 1 10

Vignette 2 12

Slides for Introduction 14

Storyline Planning Tool – Overview 14

Blank Storyline Tool 16

Example Storyline Planning Tools 17

References 25

Description of the Storyline Tool

Background information

The Storyline Tool is designed to create a sequence of lesson activities according to a coherent narrative that is motivated by investigating the phenomenon or problem at the center of the unit. The storyline Tool serves as an intermediate step between identifying the key ideas taught in a sequence of lessons (unit) and the development of full lesson plans. Thus, this tool helps to further specify the sequencing of, and connections between, lesson activities while allowing for easy rearrangement and revision of learning activities before full lesson plans are drafted. The storyline planning tool is designed around the idea of a driving question, which is a question that provides context for learning about the key ideas of the planned unit and motivates a need to know about them. For longer lesson sequences, it may be helpful to use sub-driving questions to help maintain student interest and to make more complex lesson sequences manageable. The tool is constructed as a table in which individual lessons are organized into rows. Each row includes different aspects of a lesson, for example the phenomena to be investigated or what students should figure out (for a detailed description of the tool and additional information see Next Generation Science Storylines; Nordine et al., 2019; Reiser et al., 2021).

To introduce the storyline planning tool in a teacher education course, we use an approach which is similar to the idea of a phenomenon or problem at the center of the unit: the main idea of the Storyline Tool is to put a teaching phenomenon in the center of the teacher education course. Teaching phenomena can be understood as rich, authentic classroom situations that spur pre-service teachers' interest in specific teaching situations and contextualize subsequent learning. Thus, these teaching phenomena may help to motivate pre-service teachers' engagement with the storyline planning tool (see also Nordine et al., 2019).

Link to Coherent Science Instruction

To date, the Storyline Tool is commonly used as a design strategy for a project-based science curriculum (see e.g., Nordine et al., 2019; Penuel et al., 2022; Reiser et al., 2021). However, Penuel et al. (2022) reported that lessons sequenced with the Storyline Tool can increase students' perception of coherence (i.e., students "understood how today's lesson fit with their class' questions"; Penuel et al., 2022, p. 21). In addition, Roth et al. (2011) demonstrated that following a storyline approach can result in higher gains in student learning. Moreover, Reiser et al. (2021) argued that the Storyline Tool can engage students in meaningful practice and support their epistemic agency and, therefore, carry forward important shifts in teaching approaches demanded from the Next Generation Science Standards (National Research Council, 2013).

Possible Integration into the Teacher Education Curriculum

The Storyline Tool requires preservice teachers to have prior knowledge about teaching methods like project-based learning, planning of lessons about students' motivation. Thus, the Storyline Module should be integrated into an advanced method course of a master teacher education program.

Difficulties of Pre-Service Teachers

In pilot enactments, pre-service teachers reported seeing plenty of advantages of the Storyline Tool regarding their lesson planning. For example, participants reported that they have been solely engaged in planning single lessons in the past of their education program. Thus, prior to using the Storyline Tool, it was often not clear for them how to connect these single lessons into a coherent unit.

We noted that pre-service teachers often understood the idea of the Storyline Tool best when using the analogy of binge-watching series: "when science instruction unfolds like a great story, students want to know more, and they are puzzled […] as they encounter new phenomena and ask new questions" (Nordine et al., 2019, p. 87). Importantly, before implementing the Storyline Module, we introduced the *CoRe* tool to our pre-service teachers and discussed how the *CoRe* can be used to plan future teaching. When the pre-service teachers designed their first storyline, they took advantage of their *CoRe*. For example, they implemented one *big idea* as the underlying thread of their storyline and connected the sub-driving questions and phenomena to their knowledge about students' thinking. Thus, we strongly recommend introducing and practicing with the *CoRe* tool in advance of the Storyline Tool.

Some challenges in using the Storyline Tool need to be considered. For example, the pre-service teachers struggled with the "grainsize" of the sub-driving questions. Some pre-service teachers formulated sub-driving questions which were too big and went beyond the scope of one or two lessons. Moreover, some (sub-)driving questions did not originate from students' everyday life but derived from canonical physics experiments or laws, which separates the learning context from students' everyday experiences and threatens students' perception of a *need-to-know* about new science ideas. Thus, features of adequate driving question should be addressed explicitly in the module (for key features of driving questions see Krajcik & Czerniak, 2018, pp. 64). Moreover, using sub-driving questions as a structuring element to connect across multiple lessons was also challenging for preservice teachers. In other words, pre-service teachers had difficulties in sequencing the different lessons and sub-driving question in a way that they contribute to answering the unit's driving question.

Another second challenge faced by preservice teachers was crafting learning performances. Pre-service teachers might be familiar with writing lesson-specific learning goals that identify the content to be learned, but learning performances go beyond content learning goals to specify how students should engage with learning experiences and can achieve learning goals. Unlike learning goals that specify ideas to be learned, learning performance specify observable behaviors and artifacts that teachers can use to evaluate whether students have achieved the desired level of learning and ability to use their learning in the context of meaningful phenomena and problems. Learning performances blend a science practice (e.g., modeling, arguing) with science ideas (e.g., conservation of energy), and crafting learning outcomes in this way is often challenging for preservice teachers.

Finally, we observed that is challenging for pre-service teachers to find appropriate phenomena which are rich and complex enough to guide multiple lessons but easy to understand even for young students. We think that sources like *STEM LEARNING (*https://www.stem.org.uk/) or the book by Lowery (2012) can be helpful for pre-service teachers to find adequate phenomena.

Evaluation of Pre-Service Teachers' Storyline

According to pre-service teachers' challenges in using the storyline tool, well-designed storylines can be described by three characteristics: (1) suitable (sub-)driving questions that are (2) sequenced in a meaningful manner and (3) learning performances that describe how students should engage with the learning experiences and must do to show proficiency.

Checklist: Suitable (Sub-)Driving Questions

The following features of (sub-)driving questions were adapted from Krajcik and Czerniak (2018, p. 65).

Feasible	
☐	Students can design an investigation to answer the question.
☐	Students can perform an investigation to answer the question.
Worthwhile	
☐	The question is related to what scientists really do.
☐	The question is rich in science ideas.
Contextualization	
☐	The question is anchored in real-world issues.
☐	The question is interesting and important to learners.
Sustainable	
☐	The question allows students to pursue solutions over time.
☐	The question leads to new questions.

Checklist: Meaningful Sequence of Sub-Driving Questions

☐	focuses on different aspects of the driving question or phenomenon.
☐	contributes to answering the driving question of phenomenon.
☐	guides students' learning experiences within individual lessons.
☐	prompts students to ask further sub-driving questions related to the phenomenon.
☐	sequence of sub-driving questions enables students to put pieces together and construct answers of the driving question or phenomenon.

Checklist: Adequate Learning Performances

☐	list lesson-specific achievement goals, i.e., what students should know and be able to do after the lesson.
☐	capture what students must do to show proficiency.
	are the assessable statements
☐	align with the targets of the specific curriculum, the instruction, and assessment.
☐	The learning performances are three-dimensional statements that integrate science practices, disciplinary core ideas, and crosscutting concepts (see National Research Council, 2013).

Suggested Activities for Introduction

Following the idea of teaching phenomena, pre-service teacher will read two vignettes of a physics lesson as preparatory work for the module. Both vignettes feature different science instructions promoted by a physics teacher. As a starting point of this module, these vignettes were used to examining features of coherent science instruction and different ways of designing coherent physics lessons. Afterward, by introducing the Storyline Tool and examples of its use, pre-service teachers can analyze how the Storyline Tool ensures coherence among lessons and can reflect the value and challenges in using this tool for the preparation of physics lessons.

Below, a detailed overview of suggested activities in the Storyline Module is given. The materials used in this module can be found in the section Accompanying Instructor Materials. The module is designed for a 90-minutes course; however, it gives opportunities to lead a more detailed discussion with the pre-service teachers so that the course can be expanded to 180 minutes. For example, both vignettes can be read during the course instead of being read in advance of the course.

Pre-service teacher will read both vignettes as preparatory work. The task could be: "Read the two vignettes and use the coherent core to evaluate the classroom situation. What features of coherent science instructions are promoted by the teacher?"

Time	Phase	Organization	Materials	Activity	Outcome
5 min.	Introduction	Presentation	Slides for Introduction	Recapture the coherent core: short description of the four features	Coherent core can be used to characterize coherence in science instructions
15 min.	Examining the teaching phenomenon	Think, Pair, Share	White board, etc.	Discussion about similarities and differences between both vignettes.	Similarities: basic conditions like class, curriculum or the topic of the lesson. In both vignettes Ms. Hoffman structured their lesson,… Differences: The way Ms. Hoffman structured the lesson, teacher-student and student-student-interaction, the role of the students in planning the lesson, maybe students' motivation?,…
		Group discussion		Discussion about how to organize a coherent lesson. What steps do we need to structure lessons like in vignette 2?	The teacher in the second vignette puts a question in the center of the lessons. Instructions are organized around this question. Teacher promotes students' need-to-know explicitly.
15 min.	Get to know the storyline tool	Individual work	Storyline Planning Tool – Overview, Blank Storyline Planning Tool	Read the storyline tool one pager.	
10 min.		Lecture	Slides for analyzing the Storyline Tool	Talk though the storyline tool and examine the different steps of planning a lesson according to it	

30 min.	Analyze of example storyline	Work in small groups	Example Storyline Planning Tool used in vignette 2	Analyze how the storyline tool ensures coherence among units and lessons: How are the lesson-specific driving questions connected to the driving question? How are the lesson-specific driving questions connected to each other? How do the phenomena help to answer the (lesson-specific) driving question? How are the students involved in the instructions?	The storyline tool helps us to design coherent lessons: it puts a phenomenon in the center and gather students' need-to-know
15 min.	Reflection on the storyline tool	Group discussion		Discussion about the example storyline tools and the value in using the storyline tool for preparing the class. What could be difficulties in constructing a storyline? How can we overcome these difficulties? For additional reading see Nordine et al. (2019)	

Instructor Materials

Vignette 1

Ms. Hoffmann teaches a 8th-grade physics class. Most of her students are interested in science, however, their performance in physics is worse than in other science classes like biology or chemistry. Many students need special support to draw a connection between different topics in physics in order to get a bigger picture of science.

Currently, Ms. Hoffmann and her physics class are working on classical optics (see Figure 1). In the last unit (comprising about five lessons), Ms. Hoffmann and her class investigated the reflection of light at flat surfaces. They learned about the law of reflection and finished the unit by examining the refraction of light at the interface between two media. In today's lesson, Ms. Hoffmann wants to start with optical systems. Therefore, she planned an introduction to the topic "Converging and diverging lenses".

Ms. Hoffmann organizes her physics class according to the structure of physics itself.

Classical optics (8th grade)

Reflection at flat surfaces

1. Law of reflection
2. Refraction at the interface between media

Optical systems

1. Converging and diverging lenses
2. Focal length and images of converging lenses
3. Human eyes, far- and nearsightedness

Figure 1. School physics curriculum

Thus, after teaching refraction at flat surfaces, she wants her class to investigate the refraction of light at curved surfaces. Through these structures, she further hopes that her students see the connection of the phenomena and problems and, consequently, become aware of her coherent instruction. To strengthen the connection between both units, Ms. Hoffmann starts the new lesson with a brief review of the last lessons.

> <u>Ms. Hoffmann:</u> "In our last lessons, we intensively examined the behavior of light under different conditions. Can someone summarizes our results from the last lesson?"
> <u>Tim:</u> "We investigated how light travels through different materials."
> <u>Ms. Hoffmann:</u> "What do you mean by materials?" She takes a lamp and shines against a metal plate. "Look, light isn't about to shine through this material."

Lisa rises her hand hectically but Ms. Hoffmann wants to give Tim a chance to revise his answer.

Tim: "No, I mean….medium. We investigated how light travels through different media."
Ms. Hoffmann (nods in agreement): "Anyone else? Julia, do you want to add something?"
Julia: "We investigated that light bends when it passes through a prism or something like that."

Ms. Hoffmann grabs a prism, attached it to the magnetic wall. She shows how the light is refracted by the prism. Lisa raises her hand.

Ms. Hoffmann: "Who can explain this in more detail?"
Lisa: "We also saw that the angle of incidence and the angle of reflection aren't always the same."

Julian raises his hand.

Ms. Hoffmann: "Great, okay. Julian, do you have a question?"
Julian: "Yes, is the reflection of light gonna be on the test too? Because the last lesson, we only talked about refraction but not about reflection."
Ms. Hoffmann: "Yes of course! Because reflection is a really important topic in physics. But, let's come back to refraction. Can someone put the different things together? Jonas?"
Jonas: "I think, when light passes through a prism, for example, then the angle of incidence and angle of reflection are unequal."
Ms. Hoffmann: "Exactly! And that's what we call refraction".

Ms. Hoffmann grabs other objects that her class used to examine refraction (e.g., different prisms and transparent cubes).

Ms. Hoffmann: "So, if you take a look at these objects here, or rather their interfaces. What can you observe?"

Tim and Lisa raise their hands.

Tim: "Light will be refracted by them?"
Ms. Hoffmann: "Yes, that's right. What else, Lisa?"
Lisa: "The edges of each face are of equal length?"
Ms. Hoffmann: "Yes, and the surfaces are?"
Lisa: "Flat."
Ms. Hoffmann: "Yes. So, for now, we understand refraction at flat surfaces. And now we move on to the next topic. Let's inquire objects with a *curved* surface. What do you think, Tim, is the simplest curvature of a surface to look at?"
Tim: "A ball?"

Ms. Hoffmann: "A ball is an object, not a surface. But you are right, the surface of a ball is the simplest example of a curved surface. We call this surface a spherical surface. So, that is our starting point. In the next lessons, we will examine how light is refracted by spherical surfaces."

Vignette 2

Ms. Hoffmann teaches a 8th-grade physics class. Most of her students are interested in science, however, their performance in physics is worse than in other science classes like biology or chemistry. Many students need special support to draw a connection between different topics in physics in order to get a bigger picture of science.

Currently, Ms. Hoffmann and her physics class are working on classical optics (see Figure 1). In the last unit (comprising about five lessons), Ms. Hoffmann and her class investigated the reflection of light at flat surfaces. They learned about the law of reflection and finished the unit by examining the refraction of light at the interface between two media. In today's lesson, Ms. Hoffmann wants to start with optical systems. Therefore, she planned an introduction to the topic "Converging and diverging lenses".

Classical optics (8th grade)	
Reflection at flat surfaces	**Optical systems**
3. Law of reflection 4. Refraction at the interface between media	4. Converging and diverging lenses 5. Focal length and images of converging lenses 6. Human eyes, far- and nearsightedness

Figure 2. School physics curriculum

In order to support her students to see the connection of phenomena and problems, Ms. Hoffmann and her class develop a so-called driving question. The units and lessons are driven by this driving question in a way that each unit is guided by a sub-driving question that focuses on specific aspects of the driving question. In this way, students were supported in connecting topics over the course and, consequently, become aware of instructional coherence.
Ms. Hoffmann and her class investigate both units of classical optics under the driving question *„How can we see objects that are far away?"*. In order to answer the driving question, Ms. Hoffmann's class examined the reflection at flat surfaces under different sub-driving question, e.g. *„What can cause light to bend?"*. Ms. Hoffmann wants her students to examine the next unit (optical systems) under the sub-driving question *„Why do some objects make things appear larger and others not?".* Ms. Hoffmann starts the lesson.

Ms. Hoffmann: "During the last lesson, we examined how we can manipulate the direction of light."
Julian: "Light is changing its direction if it travels from air into water, for example."
Lisa: "Maybe, when light is bent, that's how we can see objects that far away. Can we do an experiment on that?
Ms. Hoffmann: "Okay, that sounds reasonable. But first, let's summarize what we already know."
Tim: "We know that light can be refracted."

Ms. Hoffman takes a lamp and shines against a metal plate.

Ms. Hoffmann: "But in this case, the light is not refracted, isn't it? So, can you explain, when refraction occurs?"

Lisa rises her hand hectically but Ms. Hoffmann wants to give Tim a chance to revise his answer.

Tim: "So, I mean… light is refracted when it passes through different media."
Ms. Hoffmann: "All right, that's what we already know. So, let's come back to Lisa's idea."
Jonas: "So, the refraction of light affects how objects appear."
Lisa: "Yes! I think, this is how we can see objects that are far away."
Tim: "We need to find out if objects can refract light in a way that we can see them from far away."
Ms. Hoffmann: "Okay, let's do a scientific investigation on that. So, we already know that for some objects light can go through them, right? For example this cube. So, let's position this cube in front of a picture."

Ms. Hoffmann takes a transparent cube and attached it in front of a picture so that the students can look at the picture through the cube.

Ms. Hoffmann: "Who would like to report what he or she can see?"

Ms. Hoffmann waits a moment so that all students can think about the result. Lisa raises her hand.

Lisa: „When I look through the cube, the picture appears normal."
Ms. Hoffmann: "What do you mean by *normal*?"
Lisa: "The size of the picture is the same without looking through the cube."
Ms. Hoffmann: „Yeah, exactly! It seems like nothing happens to our picture when we look through the cube. Okay, I have another transparent object here."

Ms. Hoffmann gabs a convex lens and positions it at the same distance from the picture as the cube.

Ms. Hoffmann: „Alright, what do you see now?"
Tim: "When I'm looking through this round object, the picture appears kind of zoomed in."
Lisa: "So, this object on the left side can manipulate the light passing through."
Julian: "Maybe, this helps us to answer how we can see object far away."
Ms. Hoffmann: "Okay, based on your ideas, what could be the question for our next lessons?
Tim: "Why some things appear larger to us?"
Julian: "We need to consider Lisa's idea that objects manipulate light. Maybe, the question could be why do some objects make things appear larger and others not?"

Slides for Introduction

The slides for the introduction of the Storyline Tool as well as the analysis of the Storyline Tool can be found on the project's website www.decoste-project.eu.

Storyline Planning Tool – Overview

Purpose
The storyline planning tool is designed to create a sequence of lesson activities according to a coherent narrative that is motivated by investigating the phenomena or problem at the center of the unit.

Design of the storyline planning tool
The storyline planning tool serves as an intermediate step between identifying the key ideas taught in a sequence of lessons (unit) and the development of full lesson plans. Thus, this tool helps to further specify the sequencing of, and connections between, lesson activities while allowing for easy rearrangement and revision of learning activities before full lesson plans are drafted.

The storyline planning tool is designed around the idea of a *driving question*, which is a question that provides context for learning about the key ideas of the planned unit and motivates a need to know about them. For longer lesson sequences, it may be helpful to use *sub-driving questions* to help maintain student interest and to make more complex lesson sequences manageable.

Using the storyline planning tool

The tool is constructed as a table in which individual lessons are organized into rows. Each row includes four columns: (1) lesson-specific question, (2) brief description of the learning activities, (3) phenomena to be investigated, (4) what student figure out, and (5) lesson-specific learning performances.

Lesson-specific question
These questions drive individual lessons and can be addressed within a single investigation. For example, in a unit based upon the driving question “Why do I need to wear a seat belt in a car?”, a single lesson may be “What affects the friction force between tires and the road?”

Phenomena to be investigated
This column lists the phenomena to be investigated during learning activities in the lesson. This column helps to clarify what real-world events, devices, and/or problems students focus on investigating.

Brief description of learning activities
Descriptions summarize what students will do in the lesson and illustrate how the lesson builds upon previous lessons and sets the stage for subsequent lessons. Keep them short – long descriptions can be unwieldy.

What students learn
This column clarifies the key science ideas and/or relationships that students figure out during the learning activities in a lesson that help them to build toward answering the driving question.

Lesson-specific learning performances
These are statements that blend science principles and practices into observable performances that serve as the basis for teachers and students formatively assessing student progress. Learning performances are a natural outgrowth of students’ engagement in the lesson learning activities.

Blank Storyline Tool

Driving question:					
Lesson (number and topic)	Lesson question	Phenomenon / experiment	Description	What students figure out (physical term, concept, principle, law, …)	Learning performance (how students use science ideas as they engage in science practices)

Example Storyline Planning Tools

Primary school

This example is an adapted excerpt from the Next Generation Science Storylines (https://www.nextgenstorylines.org/)

Driving question: Where Does Our Clean Water Come From and Where Does It Go After We Make It Dirty?					
Lesson (number and topic)	**Lesson question**	**Phenomenon / experiment**	**Description**	**What students learn (physical term, concept, principle, law, …)**	**Learning performance**
1 – 3	How do we clean dirty stuff?	Dishes get dirty after you use them. When we wash those dishes in a sink or dump dirty water down the toilet, the dirty stuff goes away down the drain, while cleaner water enters from the faucet (or some hidden part of the toilet).	Students develop initial models showing where water and anything that is "dirty" goes once it enters a drain in their house and where the water coming out of the faucet comes from. After a consensus building discussion, the class develops a consensus model of this system that led them to realize that there is still much that is unknown about where water goes, suggesting possible investigations to determine water's path once in the drain.	In a water system there is a system output and a system input.	Develop a model to convey a process (and/or represent structures in a system) Ask questions based on observations to find out more information, brainstorm ways that these questions can be investigated in our classroom.
4 + 5	Where does all the waste that goes	Exploration of the inside of pipes and the maze of pipes	Students will watch a video of a plumber trying to	"Dirty" water (i.e., the water system output) needs to be	Obtain and communicate

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	down the drain go?	underground, as well as a visual introduction to what happens at a wastewater treatment plant	retrieve an item lost down the drain as a safe and accessible alternative to putting a camera down the drain or knocking down a wall behind a sink/toilet. Using three ideas seen from the video (water traveling downwards, pipes getting bigger as water goes down, and water entering a large pipe of already flowing with water), students develop a model to explain where water goes after entering the drain. Comparing their models to actual photographs and diagrams, students then develop questions about where the water in the large pipe (i.e., sewer) goes.	treated. This happens at wastewater treatment facility. These facilities are proximity to bodies of water.	information across reliable media sources Develop and use a Model to revise the initial model (from the previous lesson)
6 – 9	How do we clean (and make) dirty water?	Creating dirty water (with everyday household items) Trying to clean the water by filtering out the dirty stuff from the water (with everyday household materials)	Students will make dirty water in order to figure out how it is cleaned at the wastewater treatment plant. They will design multiple investigations to figure out how various technologies clean the water, along with analyzing the data from the	Cleaning "dirty" water from items requires different technologies like colanders or coffee filters. If items are smaller than the holes in the technologies, they can pass through, which is why the water is still dirty.	Plan and conduct an investigation collaboratively using fair tests in which variables are controlled and the number of trials considered, evaluating appropriate methods

			investigations to see how effective they are at cleaning the water. Students will also develop an initial model that explains why some of the items in the dirty water were able to filter and why others were not.		and/or tools for collecting data, and making observations and taking measurements to produce data to serve Develop and use a model to explain result from this investigation

Middle school

Driving question: How can we see objects that are far away?					
Lesson (number and topic)	**Lesson question**	**Phenomenon / experiment**	**Description**	**What students learn (physical term, concept, principle, law, …)**	**Learning performance**
1 Introduction	How can we see objects that are far away?	A camera records the moon. After zooming, the structure of the moon's surface can be seen clearly. Historical figures from the moon.	The teacher shows a short film, which demonstrates a camera zooming on the moon (e.g., https://www.youtube.com/watch?v=KN-4pUI1RzQ). In addition, the teacher presents historical figures	Objects that are far away (e.g., the moon) can be seen without modern technology like cameras. Even people in the early 1600 were able to detect, for example, the structure of the moon's surface.	Based on figures and videos, students were able to observe and describe a phenomenon and can pose questions that help to explain the phenomenon.

			from the moon (e.g., from Scheiner, Biancani or Malaper in the early 1600, see e.g., http://galileo.rice.edu/sci/observations/moon.html) to empathize that people were able to see objects far away already 400 hundred years ago. Students observe the phenomena and develop in collaboration with the teacher the driving question (How can we see objects that are far away?) and possible sub-driving questions.		
2 Reflection	Why do we see an object?	An object is placed inside a shoebox (open site facing the front), which is painted blank from the inside. A flashlight is placed beside the box so that the flashlight shines parallel to the open site. If all other light sources (except the flashlight) in the room were switched off, the object inside the box is not visible.	The teacher explains the setting of the experiment. Students hypothesize if the object inside the shoebox is visible if (1) no light source in the room is switched on, and (2) only the flashlight is switched on. The results from the experiment are explained using the ray model of light.	We can see an object if it either emits light or it reflects light from an emitting light source.	Based in the ray model of light, students were able to explain why objects are visible for us or not.
3 + 4 Reflection	How can we see objects that are	Mirrors are used to direct a laser through a maze.	Students are divided into small groups. Each group	With the help of flat mirrors, lights can be reflected so that	Students are able to conduct an

	hidden from our view?		gets a laser, a maze printed on paper as well as some flat mirrors. The task is to direct the laser through the maze by using as few mirrors as possible. Students sketch the position of the mirrors and the laser in the maze, measure the angle of incidence and reflection. All groups present their set-up and, the group with the fewest mirrors wins. The law of reflection is derived from students' diagram by the class.	the ray of light reaches the eyes. When light is reflected by a flat mirror, the angle of incidence equals the angle of reflection.	experiment and analyze data to derive the law of reflection.
5 + 6 Refraction	What can cause light to bend?	Water and a water-sugar-solution is separately added to a clear container. A laser beam passing straight through the upper part of the mixture will not be bent. A laser beam showing down the length of the container will be bent.	The teacher shows the experiment. The students conclude that the properties of the water have to change inside the container. The teacher introduces the term *medium*. The students hypothesize that light is bent when the medium changes (i.e., as it passes through the interface between two media). Teacher and students plan different experiments to	If light passes through the interface between two media (of different refractive indices), it will be refracted. The angel of refraction depends on the two media.	Students were able to plan and conduct an experiment and can analyze data in order to explain how light behaves at the interface between two media.

			examine the refraction of light. Students conduct experiments and analyze the results.		
7 Converging and diverging lenses	Why do some objects make things appear larger and others not?				

High school

This example is an adapted excerpt from the Next Generation Science Storylines (https://www.nextgenstorylines.org/)

Driving question: Why Do Things Get Colder (or Hotter) When They React?					
Lesson (number and topic)	**Lesson question**	**Phenomenon / experiment**	**Description**	**What students learn (physical term, concept, principle, law, …)**	**Learning performance**
1 – 3	What happens when room temperature substances are mixed together?	Primary: When ammonium chloride and barium hydroxide are added in a beaker, the beaker will freeze to a wood block. Secondary: Mixing baking soda, water, and pink lemonade also results in a drop in temperature.	Students will observe a perplexing anchoring event: mixing together two different room temperature substances in a beaker results in it cooling, so much that the beaker freezes to a wooden block. Students develop models to try to explain this phenomena.	Chemical reactions can result in a drop in temperature. Scientific models should be general in the sense that they can explain as much phenomena as possible. The more molecules move, the more kinetic energy they have and the hotter the	Ask questions that arise from careful observation of unexpected results, to clarify and seek additional information Develop a model based on evidence

			Together with the teacher the class agree on aspects of the phenomena that need to be accounted for a representations to use for particles and temperature changes that they want to use in future explanations and models. Students will develop a driving question board.	substance is. We call the average kinetic energy of all the molecules in a substance the substance's thermal energy. Thermal energy can be measured by finding a substance's temperature.	to illustrate the relationships between components of a system
4 + 5	Will the temperature still drop if we mix two things and no chemical reaction occurs?	Dissolving potassium chloride in water results in a temperature drop.	Students explore a physical change, the dissolution of salt in water, and discover that it also results in a drop in temperature. They try to understand what exactly is happening when salt is dissolved in water and they convince themselves that this phenomena is indeed a physical change and not a chemical reaction.	Processes besides chemical reactions (e.g., dissolving) can also absorb thermal energy which results in a drop of temperature. Dissolution can be understood as a substance splitting into smaller and smaller pieces until it can no longer be seen, but it is still there.	Plan and carry out investigations to produce data to serve as evidence
6 + 7	How does air cool some things down and warm other things up?	If a beaker of water of one temperature changes temperature when placed in a closed box surrounded with room temperature air, the temperatures of both the even out over time- one gets colder, one gets warmer.	Students will explore temperature to better understand generally what temperature is and how things change temperature. Students will study systems of changing temperature and come to a consensus that (1) everything has	Thermal energy can be transferred through particle collisions, even when we don't intermix the particles together Energy doesn't disappear, it gets transferred to something else	Ask questions and evaluate them to determine if they are testable and relevant. Engage in Argumentation from Evidence and

			thermal energy; (2) a change in thermal energy can be explained through particle collisions; and (3) energy is always conserved in a system.	Everything has thermal energy	respectfully provide and receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions

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