eROBSON learning scenario design template

Authors: Giel van Lankveld, Olga Firssova, Nardie Fanchamps, Dimitris Karampatzakis, Gregory Milopoulos, Iliana Ntovolou, Gene Bertrand, Krist Shingjergji, Roland Klemke, Corrie Urlings, and Mikhail Fominykh

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Acknowledgement

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About the eROBSON learning scenario design template

This learning scenario template is to be used in an interactive workshop with teachers familiar with Educational Robotics (ER) and without or with limited background in Augmented Reality (AR). In the workshop design support will be provided by AR and/or ER experts.

Participating teachers get a short introduction in the eROBSON approach of ER support with AR and a demonstration of two eROBSON tools (ARTutor and MirageXR) in combination with a hands-on experience with both tools. eROBSON experts will support designing initial scenarios for their own educational contexts.

Such scenarios can be designed to a) substitute current ER teaching scenarios (i.e., reaching the same instructional goals as in live /current teaching without modifications or improvements; b) introduce modifications (slight functional improvements); c) substantially modify and improve current scenarios of teaching ER (based on Puentedura, 2010, SAMR-model).

Principles of Successive Approximation model (SAM) and Design Thinking (DT) are taken as the backbone of instructional design methodology (see Attachment for details on these approaches and on an introduction to ER, AR and some examples).

Table of Contents

Phase 1. Inspiration: Initial ideas, inspirations and thoughts

Demonstration of eROBSON approach as a source of ideas and inspirations (See and experience /Δείτε και βιώστε/Se og opplev/Zien en ervaren)

This phase is meant to frame design activities of participating teachers. Therefore the approach and the tools are first introduced and demonstrated to participants. Hands-on exercises might be a welcome addition if it is feasible (!). Filling in the provided template has two goals: to ensure understanding of the approach and to trigger participants in the direction of their own solutions, be a point of departure in their own design (phases 1 and further).

1.1. Upon the introduction to eROBSON approach

Write down your first impressions, thoughts and ideas based on the introduction of the eROBSON approach in keywords or full sentences. Also write down questions raised by this introduction.

Impressions, thoughts, ideas Questions:

1.2. Upon the demonstration of ARTutor and/or MirageXR and a hands-on session

Write down your first impressions, thoughts and ideas based on the demonstration and hands-on session in keywords or full sentences. Write down your questions.

What application did you experience in the hands-on session? ARTutor / MirageXR

1.3. Ideas for my own lessons (optional at this stage)

What (new) opportunities do you see for applying the eROBSON approach and/or the demonstrated tools? Write down any idea or thought, however fleeting, that this demonstration gave you? Write down questions to the eROBSON experts. If you have a particular problem or issue in mind you can describe it here as well.

Ideas: Questions: Problems to tackle:

Phase 2. Preparation: Designing my own eROBSON solution

Empathize & Define: Needs, ambitions and aspirations, challenges and barriers

In this phase, you will work on your own design based on and/or inspired by demonstrated eROBSON tools and solutions. You choose the scope of this design activity (i.e., a unit) yourself - it can be a lesson, part of a lesson or a lesson series. You will be asked to describe a broader context of this activity and some basic pre-requirements.

2.1. Scope of my design

Write down if you want to design a series of activities with a common instructional goal, a single activity. You can have a lesson, a series of lessons or a part of a lesson in mind. Please, describe the activity (or activities) in concrete terms.

For example, I would like to design a single lesson in which I introduce basic ER components that we will be using in the lessons for the whole year. I want pupils to get familiar with different forms, shapes, colors and get a general idea that differences are meaningful. I have a relatively short activity in mind. For example, I would like to design a series of activities with a common instructional goal. The lesson will have an ER activity and the use of an AR tool (ARTutor).

2.2. Context, target group, pedagogy

Describe the broader context of your design (the greater whole your design will be a part of). It can be a particular course or a module, intended for a specific target group or several target groups. If applicable, indicate what pedagogical approach you would like to follow in your design (or on which this bigger whole is already based). Fill in what is applicable.

Context: Target group(s): Whenever applicable, add relevant details about background knowledge / experience Pedagogies (if applicable, select from examples. Add relevant details) ● direct instruction ● inquiry learning ● problem-based learning ● discovery learning ● self-directed learning ● learning by design ● etc.

For example, the context of the design is a series of self-study lessons based on self-directed learning principles. The goal of the whole series is to teach the basics of an electronic system (general knowledge & content exploration). Students are 13 years of age but can be older. It is a beginner's course in ER.
For example, the design will be a part of robotics lessons at grade 7 (12-13 years old) at primary/high school. The goal of the whole series is to teach about Mars using ER and AR tools.

2.3 "How can eROBSON help?"

Please, check all relevant boxes and indicate in your own words what you plan to do differently from what you are doing now. Are you looking for substitutes of the current design? Are you looking for changes (improvements, modifications) to the current design? You might find points jotted down in phase 1 helpful.

I am looking mainly for

- substituting f2f teaching by alternatives that do not require f2f presence in the same place
- substituting and slight modifying the current (course, lesson, activity) design
- major changes in the current set-up are part of my plan
- etc.

For example, I would like to provide distance learning in a self-directed and self-guided way independent from what is happening in class. Students should be able to explore the whole ER set that we will be using throughout the school year on their own. Currently, students are dependent on the teacher explaining the material and giving instruction. Transition to independent self-guided work can be seen as a major change. Our goal is to improve and enrich learner experience, not only to find substitutes for current f2f solutions.
For example, our goal is to improve and enrich learning experience by connecting ER with AR. For example, students should be able to make a Mars rover using Lego, programming it on SCRATCH language and visualizing the Mars background (or information about Mars) using ARTutor.

2.4. Specific pre-requirements and considerations

Are there any specific considerations or pre-requirements that need to be taken care of prior to design activities /to ensure success?

For example, teachers have no experience with self-guided and independent student learning. Up till now the prevailing pedagogy was direct instruction. Teachers might need extra schooling.
However, teachers are experienced ER teachers and have some basic understanding of AR. We expect that a basic training in ARTtutor and MirageXR authoring tools will be sufficient for our teachers to start developing their own lesson material. In all cases ARTutor and MirageXR need to be installed on students' smartphones.
For example, teachers have to be experienced at ER robotics. Moreover, they have to be familiar with implementing ARTutor at their lessons. Moreover, it is necessary that students

have their smartphones with them or the school should provide equipment, for example tablets.

Phase 3. Design: Iterative Design design-prototype-review

Define & Ideate: Learning objectives – activities - content – learning outcomes

In this section, the teacher works closely with a designer/developer (or development team) with eROBSON expertise. The teacher takes the lead in formulating the design and provides details on how the design will be used or should be used. An eROBSON expert supports the teacher with suggestions based on the selected tool (ARTutor or MirageXR) and AR expertise.

This section assumes there is only one learning activity. If there are multiple learning activities, such as in a complete course, there can be several templates filled in for each.

👉 This phase is not linear but is envisaged as a series of iterations.

👉 Each block can be revised, adjusted and extended in a next iteration.

Development and implementation of course contents and materials is foreseen in section 3.

3.1. Title of the course / activity

For example, The basics of an ER system by using Littlebits and ARTutor.

3.2. The learning activity as intended (and to be designed)

Describe the intended learning activity as specific as possible from the perspective of the learner (what does the learner or what do learners do, what does the teacher do to instruct, support, assess this learning?)

You are invited to think out-of-the box, take the ideal situation in mind, try not to be restricted by the available or not available facilities and tools. Feel free to combine f2f, online and blended learning formats to the best of your understanding.

For example, in the online format the planned learning activity will give the opportunity to the learner to design basic systems using AR augmentations. The learner will be guided by ARTtutor. The student will receive initial instruction by e-mail and will also receive material that will need to be printed in cut in cards. Other than that the learner will be on his/her own. After the activity is completed successfully or if the student gives a signal that three attempts failed and he/she is lost, a f2f session will be arranged.
For example, in the course there are 5 activities foreseen/included. Each activity is about designing a circuit. In order to create the circuit students will need all the printed material with a phone and the ARTutor web-app. For each component a 3d model will be available in the library All 5 activities will be supported with additional video's (instruction, exercise, explaining, self-evaluation).

For example, the planned learning activity will give the opportunity to the learner to design basic systems using AR augmentations. The learner will be guided by a tutorial. The student will receive initial instructions for the construction of the robot-rover with LEGO and will also have been taught to use ARTutor.
In the course there are 3 activities included. The first activity is to make their rover, the second to program it and the third to make the Mars background and use ARtutor to pop-up messages/information about its surface, for example. In order to create their rover students will need instructions and lego bricks, motor, controller, sensors, a tablet to program it and all the printed material with phone and the ARTutor web-app.

3.3. Aspired learning goals/aspired learning outcomes

What should the student know, understand and/or be able to do (better)?

For example,., having completed the activity the student will ….

- ☐ know the difference between the Little bits components
- ☐ be able to connect the components so that to complete the circuit
- ☐ …

For example, having completed the activity the students will be able to program an ER component and connect it with AR components.

3.4. The learning activity in detail

List the details (actions of the teacher and student or students in the order you expect them to take place, use a worksheet or construct a schematic representation of the activities in a flowchart or other type of visualization/diagram, if this works for you). Try to be as specific as possible as to what triggers an action and what follows after.

3.5. Content components

List content-related components (information & instruction, when applicable also media used to present information) that you want to use in the learning activity. It can be a theoretical introduction on paper, through video or given by the teacher live. Provide an explanation of the action that will accompany the content presentation (if applicable).

For example, video presentation (watch and answer questions)

3.6. Intended application of AR in the learning activity

a. Describe (if possible) the intended application and function of AR (check all that apply and add if necessary for what purpose AR will be used. Provide explanation or specifications (if applicable)

- ☐ For written instruction to a series of activities
- ☐ For providing information /instruction in just-in-time mode
- ☐ For self-evaluation
- ☐ For guided self-study
- ☐ For interaction with peers
- ☐ …

For example,. It will provide educational information on the subject of the ER activity

b. Explain how you think to use AR for the purpose (or purposes) you indicated above.

For example, AR would be supplementary to the activity. It would be a scene like a mockup of the surface of Mars. There will be QR codes, so that when the students scan QR codes, there will be pictures and information about Mars, the context where the robot will solve tasks.

Assistance from an AR expert might be necessary.

c. Select AR-ER mechanics that are necessary for the design idea to be implemented

👉 Assistance from an AR expert might be necessary on this step.

1. AR visualization of 3D models of ER components (either on markers/targets using image recognition or markerless using spatial mapping)
2. AR visualization of additional contextual information for the 3D models of ER components (e.g., marking inputs and outputs, current direction, “has power” indicator)
3. AR visualization of additional contextual information for the physical ER components, placing this information in the space of the ER component (using object recognition)
4. Manipulation (e.g., zooming, rotating) of the 3D models of ER components through the AR device interaction interface (e.g., by touch-screen on a smartphone, a controller, or hand-recognition and tracking on AR devices)
5. Interaction with AR markers/targets on which the 3D models of ER components are displayed (using image tracking)
6. Interaction with physical ER components on which additional dynamic contextual information is displayed (using object recognition)

7. AR visualization of other media content than 3D models of ER components (e.g., flat images, videos, text pop-ups, links, etc.)
8. Interacting with the interactable ER components (e.g., switching the button on and off, sliding the dimmer left and right)
9. Interaction between the AR visualizations of the ER components (e.g., snapping them together)
10. Simulation of the ER components interaction in circuits (e.g, each ER component changes its state based on the configuration of the circuit it is part of).
11. AR visualization of any media content useful for the scenario but that does not need to be attached to ER components (e.g., a guide, tutorial, voice instruction, etc.)

3.7 ER components (if applicable)

List here which ER components and practices will be used if relevant in your design. Consider how these ER components could potentially be supported by means of the application of AR.

For example, we will create a rover with Lego and use the distance and color sensor. A possible activity could be if "the rover detects (sees) by its sensor use a specific area on the surface map" this map could appear in ARTutor.

If you are new to the usage of sensors and have to use the components/parts to make models as applied requirements. In this way applied, AR Can help to understand what a component is, how it functions and how it should be programmed to acquire conceptual understanding.

3.8. Interaction

a. Describe overall interaction

How will you describe interaction between teacher and student, teacher and learning materials, student and student, student and learning materials in relation to the use of AR (ARTutor or MirageXR)? You may use steps 3.2. and 3.4. to add relevant information to the flowchart or overview you had created.

It might be useful to further elaborate on 3.6 and specify more in detail the interaction and learning processes with regards to the combination ER/AR and with respect to the AR features, depending on the ER scenarios/activities that the supervisor/teacher wants to implement.

For example, teachers will guide students to the learning activity. Teachers have to explain to students how ARTutor works and then students using their imagination will apply it to their project

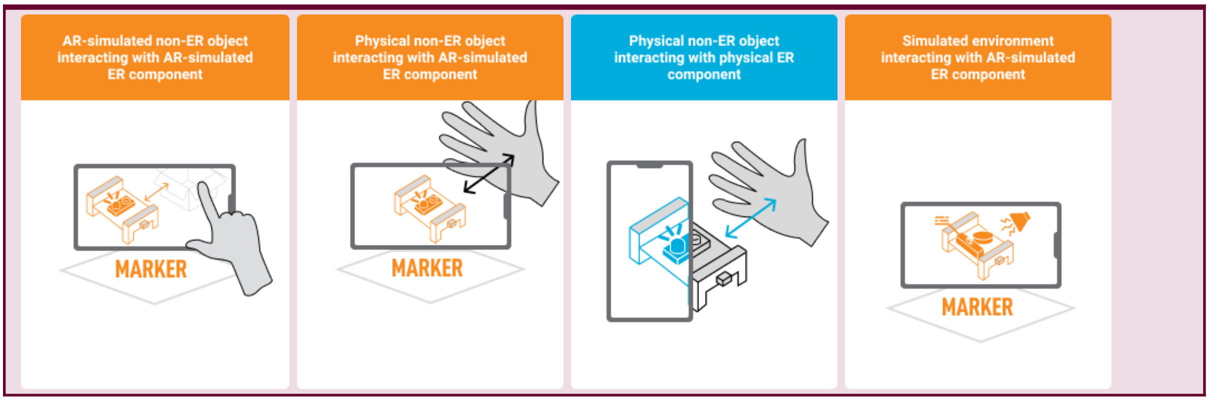
b. Specify the interaction design with AR-ER affordance cards

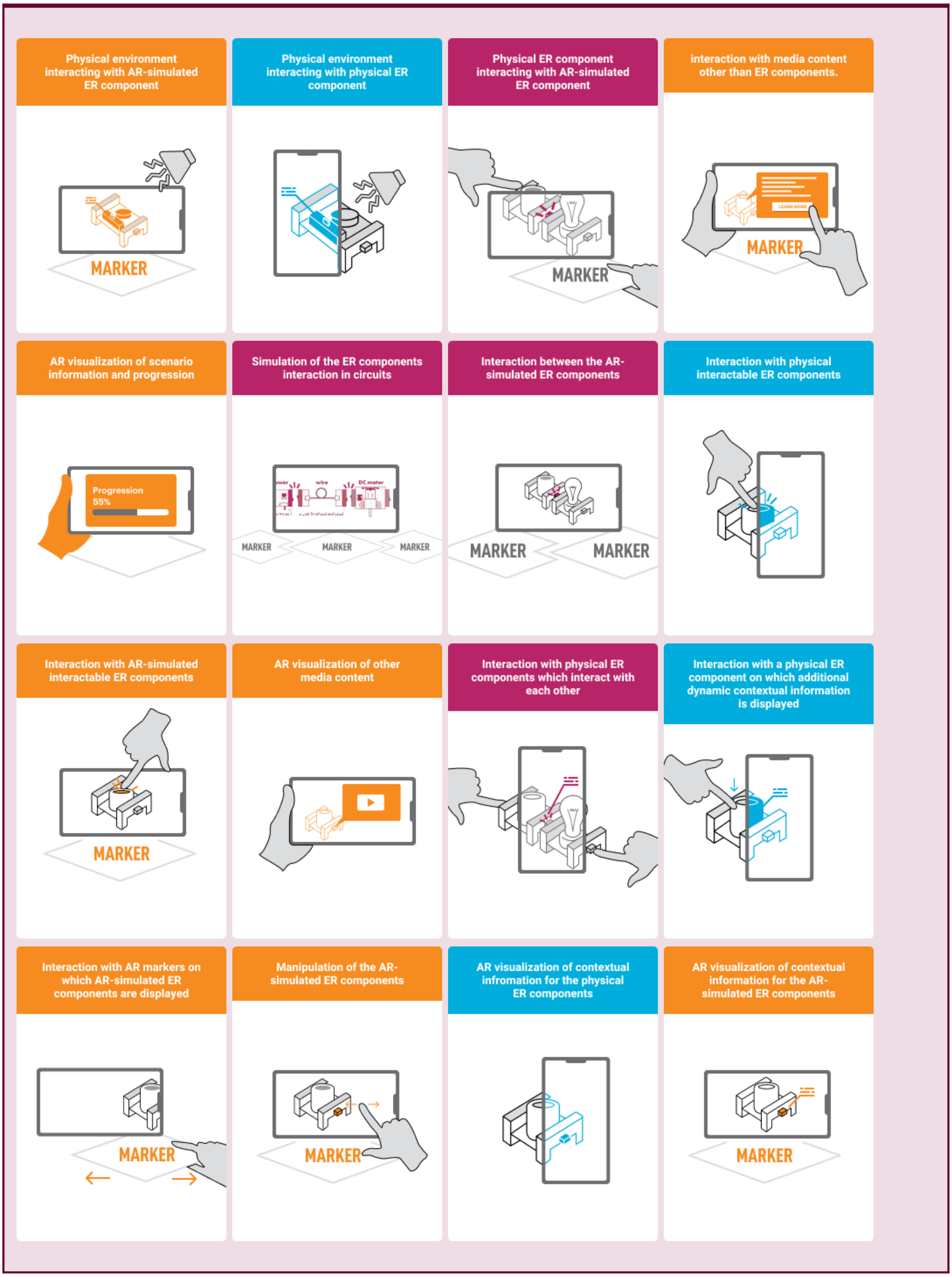
Based on the initial design iteration, in consequent iterations use the AR-ER affordance cards to combine in one design the sequences of the learning activity, AR mechanics mentioned in 3.6 c, and the interaction design.

In order to facilitate the design phase of the proposed methodology, we designed a set of cards. These cards are meant for teachers and instructional designers, who might have expertise in either ER or AR. Each card represents a different AR affordance in the context of ER. A designer of an AR-ER activity can use these cards to learn about the possibilities of an AR-ER system and to connect a scenario design to the technological affordances. The cards illustrate multiple properties of AR in an AR-ER system.

- First, they illustrate types of displayed content and user interface. An AR app can show a 3D model of ER components in an AR space and other media content in the same AR space. An AR app can also display user interface elements and other media content in the screen space (not in the AR space). An AR app can also visualize components of a simulated environment, such as noise level, ambient temperature, and similar.
- Second, the cards illustrate interaction types. Interaction is depicted on the cards with the hand elements. The user can interact with AR content via the user interface of the AR device or can interact with the physical elements - an image marker or a physical ER object. An AR app can detect a physical interaction (e.g., between a physical ER component and the physical environment) and support a simulated interaction (e.g., between a sensor type ER component and a simulated environment state).
- Third, the cards distinguish between the physical and the AR-visualized elements of the AR-ER experience. The cards that illustrate how an AR app can work with physical ER components are colored in blue, while those that show how an AR app can work with AR-simulated ER components are orange.
- Finally, the cards illustrate different recognition types. Both marker-based AR and marker-less AR are illustrated with the marker element under an ER component. Object recognition is used when physical ER components are to be augmented.

The AR-ER affordance cards are available as a supplement to this learning design template.




Physical environment interacting with AR-simulated ER component
MARKER
Physical environment interacting with physical ER component
Physical ER component interacting with AR-simulated ER component
MARKER
interaction with media content other than ER components.
MARKER
AR visualization of scenario information and progression
Progression 55%
Simulation of the ER components interaction in circuits
wire
DC motor
MARKER
MARKER
MARKER
Interaction between the AR-simulated ER components
MARKER
MARKER
Interaction with physical interactable ER components
Interaction with AR-simulated interactable ER components
MARKER
AR visualization of other media content
Interaction with physical ER components which interact with each other
Interaction with a physical ER component on which additional dynamic contextual information is displayed
Interaction with AR markers on which AR-simulated ER components are displayed
MARKER
Manipulation of the AR-simulated ER components
MARKER
AR visualization of contextual infromation for the physical ER components
AR visualization of contextual information for the AR-simulated ER components
MARKER

3.9 Formative and summative assessment

How will the learning outcomes be measured? What instruments might be used for formative and/or summative purposes?

For example, two feedback evaluation sheets will be used, one for students and an other for teachers to complete

Are you satisfied with your design so far? Design in iterations

Go through steps 3.1 to 3.9 reviewing the design-under-construction and specify your description based on your communication with the eROBSON expert and/or your improved understanding. Repeat the cycle of design until you are satisfied with the design backbone of the intended learning activity. You may number the iterations (3.2.1, 3.2.2. etc)

Additional components for the design template include but are not limited to the provided components. You may enrich the template with additional fields to specify design.

Finalizing phase 3

After completing phase 3, the teacher(s)/designer(s) will have a prototype design. As part of the design process, experts and colleagues can be included to provide feedback and insights whenever required. As part of the (phase 3) design process, the design can formally be reviewed. Review can be done together with the design(er)/(design team), by independent experts, and by the target audience.

Phase 4. Development: Iterative Development develop-implement-evaluate

Development is scripting of activities in detail, producing instruction, materials, tools and components, orchestrating and arranging them. In this section, the teacher (supported by an eROBSON expert) explains the choices that were made during the development of materials and implementation phase. Also, an elaboration is given regarding the educational opportunities and affordances these choices provide.

Examples of educational materials can be: software and applications, digital/electronic learning environments, paper learning materials, ER platforms, robotic setups and materials, AR applications, teaching/course plans, teaching guidelines, presentations/lecture materials, etc. The actual developed materials and links can be added in the section after this section.

This phase can involve several iterations.

4.1. Detail script of the teacher-learner(s)-tools interaction

Use your design blueprint (flowchart) created in 3.4 to support the development process and check boxes when prototypes are developed and tested.

Here the blueprint = flowchart

4.2. ER/AR materials, tools and components to be developed

Select what is applicable and add necessary details. Check when components are in place).

Make it clear where the user can obtain the necessary materials. For example,., for the ER platforms, this will be in the form of physical hardware/software kit that can either be purchased or can be made available via a loan. The required and associated AR application can be obtained via a download.

For example, ER components: Lego spike prime kit, motor, color sensor, distance sensor AR components: ARTutor app, smartphone or tablet with camera for scanning codes For example, ER components: physical ER kit, hardware (actuators, sensors) software, interface Virtual ER components: 3D models, images etc. AR components are: AR content, AR-platform or app, smartphone or tablet with camera for scanning codes, software. …

Screenshots of AR applications (and their crucial features), images and/or schematics on ER components, intended assignment outcomes, and examples of interactions with any software required by the course.
(if applicable)
Specifically for ARTutor:
Specifically for MirageXR:

4.3. Developed learning /teaching materials besides ER/AR materials, tools, components

Instruction, guidance, scaffolds materials (to be integrated in the tool or to be provided by the teacher just in time)

Provide an overview of the other, non-AR materials used. Include details on the developed learning materials when you have them (after the respective iteration).

For example

- Lego bricks with instructions for building a rover step by step
- A map/ mockup with the surface of Mars
- a worksheet for the instructions for programming with SCRATCH
- video tutorial or presentation for ARTutor

Select if applicable: teacher slides, video materials, presentations, work formats, learning tools, assignments, assessments, course schedules, teacher guides, etc.

4.4. Communication between learners /peer collaboration (if applicable)

For example, using AR app vs other tools: remote collaboration via an AR app, remote collaboration via other tools, distance/remote versus f2f collaboration.
Timing:
before using an AR app (e.g., discussion of tasks),
while using an AR app (completing tasks together),
after using an AR app (e.g., de-brief, peer feedback, and sharing of results).

4.5. Tools for monitoring, feedback, formative and summative assessment

For example, a quiz like kahoot implemented integrated in ER/AR tool or provided separately
For example, a quiz option in ARTutor
Not integrated in ER/AR tool: paper & pencil test

4.6. References and sources (if applicable)

Meta-data

Provide keywords that describe your design, this field can be filled in at any point in the process, also at completion

For example, basic systems, input, output, sensors, actuators, power supply, Littlebits, ARTutor.
Other possible categories:
Age group: language:
(Fill in if applicable)

Annex 1. Developed educational materials

Assignments

As part of the instructional design and development process, the assignment template can be used to structure one or more assignments that belong to the instructional design. Assignments should consider the tasks and associated learning goals and learning outcomes. The assignments should also include the used ER components and the used AR system with an exhaustive list of the used features, their contents and the interactions with ER and other learning materials.

An example assignment template has been created for the combination of the LittleBits ER system and the MirageXR AR software solution. Assignments that are based on alternative ER or AR technologies can use the example assignment template as a base. Please list developed assignments and attach any files as well as appendices.

Links to developed materials, other than assignments

(online repositories, course websites, etc.)

Appendices containing developed materials

(assessments, course schedules, teacher guides, etc.)

Annex 2. References

Educational Robotics

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Augmented Reality

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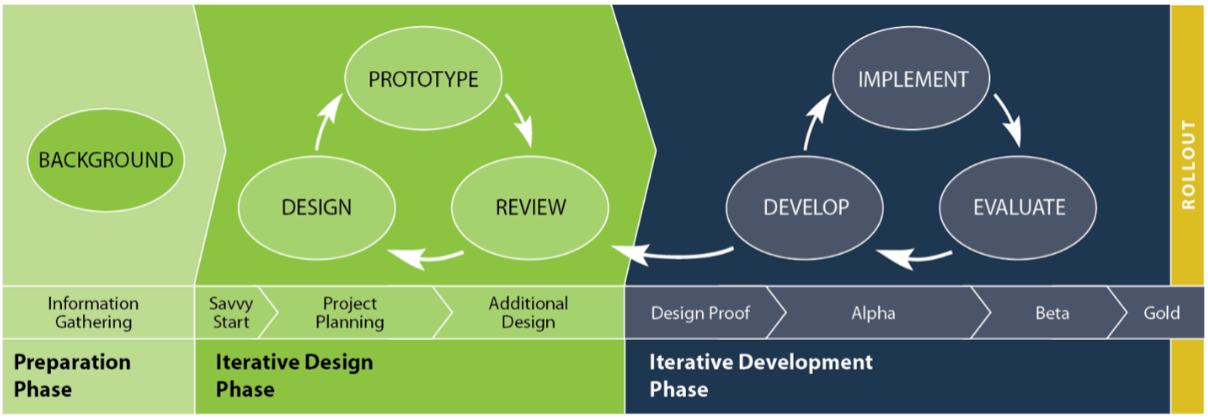
Annex 3. Theoretical Models

Successive Approximation Model



Successive Approximation Model (SAM) provides a simplified version of the well-known ADDIE instructional design methodology.

ADDIE-Model:

https://teachingcommons.stanford.edu/explore-teaching-guides/online-teaching-guide/theory-practice/addie-instructional-design-framework

SAM-Model:

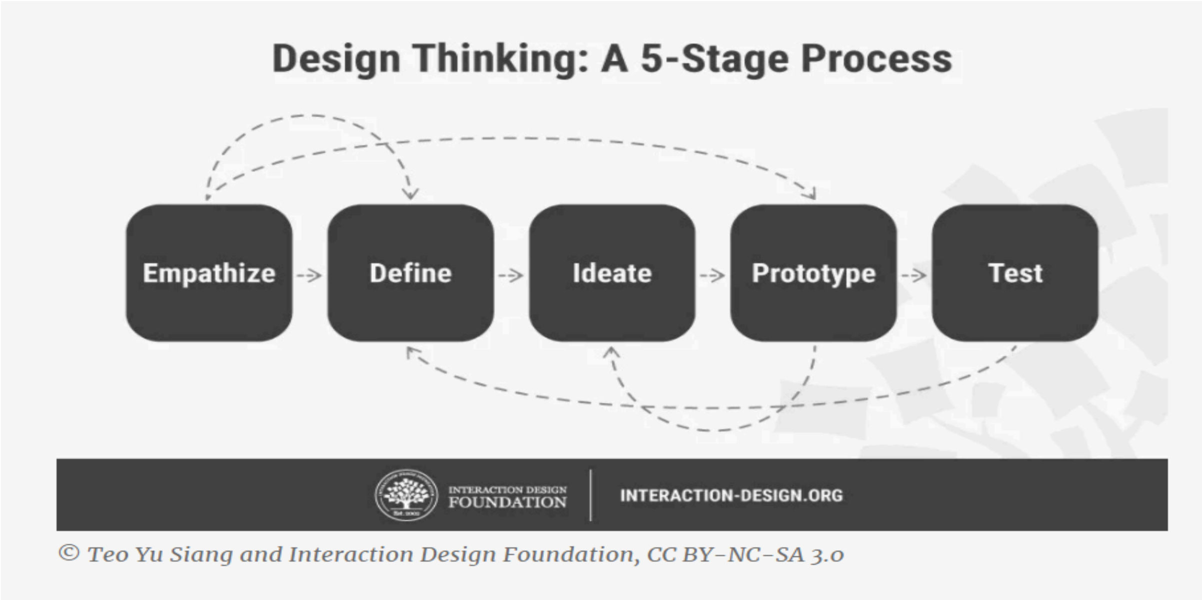
https://elmlearning.com/blog/sam-successive-approximation-model-approach/

https://dli.kennesaw.edu/resources/idmodels/sam.php

SAMR-model:

https://www.edutopia.org/article/powerful-model-understanding-good-tech-integration

Design Thinking



The Design Thinking approach can be used to generate designs in complex and technological contexts. This approach helps to adapt the intended (technological) designs to fit users and their situation. DT consists of 5 steps. The first 3 steps (empathize, define, and ideate) can fit in the "design" and "develop" steps of their respective SAM phases (see the circles in the SAM figure above to find "design" and "develop").

Design Thinking:

Design Thinking Process — Stephanie Baseman

Annex 4. Terms and Concepts

Educational Robotics

Educational Robotics (ER) refers to robotics that can be effectively applied in education, often in STEM education in particular[1]. Robotics in this context, is any system that can be programmed (through code or through composition), that can contain sensors, and that can contain moving or state-changing parts (actuators or signals). In other words, a robot does not need to look human-like. It does need to be able to receive inputs from the world around it and it needs to be able to provide a reaction (movement, lights, sounds, or activities) based on its inputs and its programming (an example of a robot could be an assembly line with sensors and welding arms for example).

There are various (popular) systems for educational robotics (LittleBits, LEGO mindstorms, Sphero, etc.). In this document we use the LittleBits system wherever we provide examples, but the described methodology is intended to be ER system-independent and other systems could be used as well.

Educational Robotics terms and concepts

In educational robotics, there are several recurring concepts and components of which we will give a brief overview here. For a complete review, see the Robotic Glossary:)[2].

Processor: the "brain" of a robot. Any component that can be programmed and that can process inputs and provide outputs for other components.

Controller: any component that receives both a desired and a currently measured position in order to steer actuators to reach specific positions.

Sensor: any component that can sense its environment and provide a signal based on its state. Common examples are: light sensor, color sensor, sound sensor, depth sensor, temperature sensor.

Actuator/motor/driver: any component that can move. Often combined with end effectors to form robotic arms or with wheels to move the robot. Multiple actuators and joints may be combined to form a (part of a) robotic arm. These are sometimes referred to as manipulators.

End effector: any component that is attached to the end of a robotic arm. For example: screwdrivers, painting sprays, or welders. Often combined with actuators to form complete robotic arms.

Power supply: any component that provides power and allows electrical components to work.

[1] https://www.iberdrola.com/innovation/educational-robots
[2] https://www.motoman.com/en-us/about/company/robotics-glossary

Augmented Reality

Augmented Reality (AR) refers to software systems that are used to enhance the real world with sensors and projected AR information. AR systems often use smartphones and headwear (glasses or goggles) to film and process the real world and then display the images together with enhancements to the user. For example: the user points his phone camera at an object and the image on the phone shows the object together with information on the object.

There are various AR systems that could be used. In this template we use MirageXR whenever we employ examples, but the methodology is intended to be AR system-independent and other systems could be used as well, as long as they provide the required features and functionalities.

AR can augment reality in various ways. It can enrich objects and locations with visible or audible information. For example: it could show a text-balloon whenever the AR device camera is pointed at an object that is recognized by the AR system, it could play audio or video whenever the AR device is within a certain range of predetermined GPS coordinates, or it could show a video or 3D model of an instructor demonstrating an activity.

An AR software application could also connect to an ER system in order to receive information about the status of its components. For example: the ER system could send the state of a color sensor to the AR system in order to help the user see if the sensor is working correctly. The AR system could superimpose the ER sensor state on any detected sensors in front of the AR camera so that the user can see the detected input and state in real time on the AR display (rather than debugging in code or through trial and error).

Augmented Reality terms and concepts

There are several important terms and concepts in AR. We provide a brief overview here.

Tracking: by using various sensors (GPS, accelerometers, digital cameras/optical sensors, etc.) the position of the AR device and (by approximation) the user can be determined. In some cases, tracking can be achieved by detecting markers (such as QR-codes).

Markers: markers are images that can be used in the real world and that can be detected by AR software. Following the detection of a marker, the AR software can take predetermined actions (such as displaying information, logging, or playing content).

Object recognition: in addition to detecting markers, some AR systems are capable of detecting objects in the real world. In the case of object recognition, the same functionalities are available as with markers. Additional information can be displayed, actions can be taken, et cetera.

Overlaying: overlaying means that the AR system is taking an image of the real world and displaying it together with additional information (that is overlaid on the real-world image). In the case of a smartphone this means that the user is pointing the phone camera at something in the real world and that the overlaid information is visible on the phone display, in the case of an AR headset it may mean that the user is perceiving the overlay as “floating in the world”.

Interaction design: interaction design refers to the design of/on AR applications that takes place in order to structure the interactions between the user and the software. Interaction design is crucial because AR application problems often stem from complex and opaque ways in which the user must use the AR system. Overly complex AR interactions can increase the cognitive load to levels that are so high that the user can no longer effectively learn.

Annex 5. Examples

An example of a STEM educational activity with ER

The goal is to learn about conditional statements in programming. ER components should be assembled to form a simple conveyor belt with a color sensor and an actuator that forms a gate. A series of blocks will run down the conveyor belt. The blocks can have three colors: red, green, or blue. Whenever the sensor detects a red block, the gate should close and divert the block off the conveyor belt. All other blocks should continue on the conveyor belt and finally drop into a container at the end of the line. Task for the students: assemble the ER set-up and use "if-statements" in the robot's programming to check sensor values and to correctly control the gate that diverts red blocks.

An example of a STEM educational activity with AR

This example is based on the ER example above. The goal is to find a mistake in the ER program code. The ER program is written so that the if-statement is triggered by blocks of all colors, rather than just by red blocks. By looking at the sensor state through AR, the students see that the sensor is detecting all colors correctly so the problem is located in another part of the robot. In addition to the sensor state, the AR system provides a floating exclamation mark ("!") that the user can touch to review information on sensor states and on using "if-statements" in code to respond to various states of ER components. Task for the students: investigate the assembled ER setup by using the AR system first and then by looking at the programming code. Report all the relevant information the AR system has provided, report what causes the problem, and fix the problem.