STEAM LEARNING ECOLOGIES

# SLEs Pilot Guidelines for collecting Learning Products (Task 4.3)

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# 1 Introduction

The purpose of these guidelines is to provide a clear and structured approach to the development and assessment of learning products within the STE(A)M Learning Ecologies (SLEs) methodology. They are designed to help educators, learners, and stakeholders understand how learning products serve as tangible outcomes that reflect the knowledge and skills acquired through educational activities. Additionally, they address practical aspects such as assessment, documentation, and the ethical management of learners' data, making them a valuable resource for implementing effective and innovative educational practices in SLEs

# 2 What is a "learning product"? What are some examples of learning products?

Learning products are educational outcomes developed by learners as part of their SLEs educational activities. These outcomes, which include projects, presentations, reports, and multimedia creations, are the tangible outcomes (physical or digital) created by students when using learning resources to undertake and complete a learning activity. These products reflect the knowledge and skills students have acquired and led to their construction. They are an integral part of the learning process, and they can serve as objects of assessment

### Ireland: Intertwined Project – Read more here

Arts and science combined in this SLE for the creation of a mosaic on the brain. The end-product was the final step of a long journey, and through each step students produced several learning artefacts.

1. Researchers introduced the medical devices for brain diagnostics and students used them to observe the anatomy of various organs/cells – learning products: **pictures** of the activity.
2. Students attended a course on understanding perspectives through a philosophical approach. – learning products: **reflections and notes** based on the course.
3. During the subsequent observation of brain images, students decided to focus on specific details of what they saw and sketch them. – learning products: **sketches**
4. Students learned about mosaic history, design, and colour theory. They then put in practice what they knew by creating a **mosaic** based on the sketches elaborated in previous steps.

In this SLE the mosaic constitutes the main learning product, but the activities that led to it (the research, the reflections and the sketches) are all important intermediated steps that tell the story behind the main learning artefact. This is the reason why it's important to document them.

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### Greece: Studying Earthquakes – Read more here

In this SLE students studied earthquakes and their waves, the softwares available to measure their characteristics, and the inner workings of a seismometer. They then built one themselves and used it to collect and analyze data.

1. Students experimented with different softwares and simulation apps – Learning products: **screenshots** of the **software code/work** created
2. They sketched the wiring system for the seismometer – learning products: **sketches**.
3. They completed the circuit and built a **scientific seismometer**
4. They collected and analyzed data – learning products: **spreadsheets** of data, **tables and graphs** based on the data.

# 3 The importance of learning products as part of an SLE

The importance of learning products is multidimensional. Firstly, they promote **active learning** and **critical thinking**. Students who create learning products move beyond passive consumption and memorization of information and are actively applying their knowledge and skills. This process requires them to analyse, synthesize, and evaluate information, deepening their understanding and developing their critical thinking skills.

Secondly, learning products encourage **creativity** and **innovation**. Students are often given the freedom to choose the format and medium of their learning products, allowing them to explore their creativity. This not only makes learning more interesting and enjoyable but also helps students develop their critical and decision-making skills.

Thirdly, these learning products provide a means for **personalized learning**. Each student can approach the creation of their learning product in a way that suits their learning style and interests. This personalized approach helps to ensure that all students are engaged and motivated, as they can connect their learning to their personal experiences and preferences.

Additionally, learning products facilitate **collaboration** and **communication**. Many educational activities involving learning products require students to work in groups, promoting teamwork and the sharing of ideas. Through these collaborative efforts, students learn to communicate effectively, negotiate, convince each other and manage conflicts, which are essential skills for both academic and professional success.

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Furthermore, learning products serve as valuable **objects of assessment**. They provide educators with a clear picture of each student's understanding and capabilities. Unlike traditional exams, which often focus on memorization, learning products allow students to demonstrate their knowledge in a practical and meaningful way. This form of assessment is more connected to real-world skills and is better at identifying areas where students may need additional support.

Lastly, learning products contribute to a sense of **achievement** and **confidence**. Completing a project or presentation can be a rewarding experience, giving students a sense of accomplishment.

# 4 Determining expected learning products for an activity

## 4.1 Link to curriculum and Learning objectives of the activity

The design of learning products should refocus on the main assumptions of constructivist learning perspectives. Namely, **the pedagogical design task should not just start from asking "what learners should do" but it should delve deeper into more details, for instance**:

- What kind of learning products would reflect learner knowledge and skills as described by curriculum standards and learning objectives;
- Which learning resources learners would need to use to create the above learning products;
- How should these learning resources be arranged to develop a learning path (i.e., sequence of learning activities);
- What kind of support (in the form of reference material or expert/teacher/stakeholder assistance or software scaffolding, if available) learners would need for using learning resources effectively;
- How much time learners would need to deliver learning products (see Hovardas, 2016a; Hovardas et al., 2018).

Additional aspects to keep into consideration when planning for learning artefacts are whether learners should work individually, in groups, or as a whole class, and if assessment of learning products will involve expert/teacher assessment, peer assessment, self-assessment or a combination of these types. Female engagement and career opportunities should also be among the criteria to be considered when designing learning products. In the sequence of steps listed above, we started from knowledge and skills (curriculum) to describe learning products and move forward. This option should be used if a STE(A)M Learning Ecology (SLE) begins from scratch. An alternative route is to start with learning products themselves and then adapt them to curriculum standards. This could be a way to transfer a SLE initiated elsewhere into a new learning context, and adapt it to the new curriculum.

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## 4.2 Availability of technology and digital tools

Technology and digital tools have increased substantially the availability of online learning resources which can be freely accessed by learners. There is a vast number of applications available to support STE(A)M projects, many of which are offered through platforms, which can contain a series of online laboratories, and which may also provide authoring tools for educators to develop learning activity sequences (see, for instance, https://www.golabz.eu/).

The availability of freely accessed online resources allows stakeholders in a SLE fill any gap they may encounter in the learning resources they would offer to learners in this SLE. Switching from physical to digital resources and from the classrooms to outdoor learning settings can lead to enriched learning experiences. **Online laboratories and applications** could further enable the creation of (digital) learning products by learners as well as data collection, processing and interpretation, favouring inquiry-based learning and the development of inquiry skills (see, in this regard, Efstathiou et al., 2018; Xenofontos et al., 2020; Hovardas et al., 2022). Stakeholder and educators need to pay attention to the various learning opportunities which are linked to the use of simulations and games, including, for instance, the presence or absence of modelling options (Hovardas et al., 2023). Finally, the **learning analytics applications** that are currently available provide multiple options to educations and other stakeholders, who may support learners in SLEs, to examine several parameters of learner engagement in real time, intervening whenever possible and desirable to try to optimize learner engagement (de Jong et al., 2021).

## 4.3 Needs and interests of other stakeholders

The focus on learning products and related pedagogical design implies that **stakeholders involved in a SLE should be invited and chosen based on their competence to offer learning resources as well as their capacity to provide support to learners** while using these resources. A fruitful but also demanding task for stakeholders in the initiation or development of a SLE is to gather available learning resources and develop learning routes based on them to engage learners in meaningful learning activities. This activity requires a participatory procedure where stakeholders share their needs and interests to develop a common vision about the SLE and plan learner engagement accordingly. **Learning products delivered as the outcome of a participatory pedagogical design could be used in the future by stakeholders** both for demonstration purposes (e.g., showcase the potential for learner engagement in SLEs), for transferring successful SLEs in new learning or geographical contexts, and for comparing trajectories and outcomes of learner groups.

In the frame of the Butterfly project in Cyprus, high school students were engaged in data collection and processing of local butterfly species in the area of their school. **A company providing gardening and landscaping services was invited to join the SLE** and worked together with students and their teachers, two university departments, a local museum and the local municipality to support students in their tasks. **The company also provided consultancy with regard to the construction of a local park funded by the municipality**, which was designed to increase flora diversity and subsequently, the diversity of butterfly species.

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**This example showcases how a private company can be successfully integrated in a SLE facilitating a citizen science project by offering learning resources which would result in new learning products** (e.g., the selection of flora species for the municipality park based on a multi-criteria decision making approach taking into account flora diversity which would attract butterfly species, interspecies competition between flora species, water demand for irrigation purposes, etc.). The contribution of this private company introduced a turning point in the SLE by propelling stakeholder interaction and learner engagement.

## 4.4 Looking beyond the worksheet and posters – using and inculcating 21st century skills.

The learning products of a SLE should ideally be different from usual outputs of class activities. It is an opportunity to explore new ways of learning due to the participation of multiple stakeholders. The expectations linked to SLEs indicate that stakeholders involved should expect from learners much more than standard worksheets and posters as encountered in traditional classrooms. To address real-world problems as envisaged in SLEs and work on solutions, learners will need to deliver learning products which would not have been produced unless the SLEs had employed a collective effort, engaging stakeholders and learners in robust and empowering communities of practice. To document such collective results, learning products need to reflect 21st century skills including communication, collaboration, critical thinking and problem solving, creativity and innovation (European Commission, 2019). There are two notes, which should be underlined at this point.

First, a **contradistinction between content and skills**: since the first is gradually becoming more available and accessible to learners in the last few decades, assessing the later has become crucial to examine the validity and reliability of content, and integrate only the relevant one in STE(A)M projects.

Second, a **contradistinction between learning settings and working settings**, which calls to reflect on the skills gap between what skills formal education can help build, opposed to the ones industries need to operate effectively. Handling SLEs as learning environments where learners deliver learning products created by themselves as solutions to community problems may contribute to closing this gap. Learning products created by learners in SLEs can be the answer of open schooling projects to bridge school and work.

During the Butterfly project in Cyprus, which was mentioned in the previous section (4.3 Needs and interests of other stakeholders), learners had to use the data they selected to take informed decisions on how to enhance flora diversity in the area of their school and the local park which was funded by the local municipality, and thereby, also enhance the diversity of butterfly species. Application of 21st century skills was of paramount importance in applying multiple criteria when considering which plant species to prioritize (e.g., based on their ability to attract and sustain butterfly species, aspects dealing with interspecies competition between plant species, demand for water, etc.). Such considerations targeted not content per se but its application to address a real-world problem. Moreover, 21st century skills would be crucial for communicating and negotiating the results of learners' inquiry to stakeholders directly engaged in the SLE (e.g., private company providing gardening and landscaping services; local

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municipality) as well as stakeholders who could provide a sustainable expansion of the SLE in other areas and neighbourhoods (e.g., the Department of Forests in Cyprus, which is responsible for urban green).

# 5 Connecting the big 3: Learning activity + Learning resources + Learning products

**We suggest two main approaches** on how to design a learning path and on how a learning resource can contribute to a learning product. **One can start by the available learning resources** and create a list of indicative learning products that learners should aim for. In this case learning resources and corresponding products should be mapped to educational outcomes or objectives. In this case learning paths are built based on the available resources, to create learning products, that achieve certain educational outcomes. Preparatory work may include deconstructing the available learning resources into elements that constitute the steps within the learning path, and give options for alternative paths for learners to follow and explore.

Furthermore, it should be noted that a particular learning resource may be more than adequate to lead to a specific learning product. It can also happen that a resource will lead to multiple products following a given learning pathway or even to a spectrum of products along different pathways. Educators should embrace this inherent flexibility because it gives them the opportunity to better categorise the learning paths and products according to various dimensions such as complexity, basic or higher levels of learning objectives, skills and competences required etc.

The approach discussed above is more straightforward and practical in nature and entails the fact that many resources if not all may be at hand in the preparation phase of an SLE. In a sense the available resources prescribe possible activities and learning paths, which is a factor to consider in a pragmatic way to assess what is feasible or not to achieve during the learning activities in each environment or setting.

**An alternative approach is to start from the conceptual side or follow a top-down perspective**. The very first step in the development process is the deep analysis of the learning objectives. For example, things to consider include: which are the priorities or hierarchies within the curriculum; can the same objectives be achieved by an instruction-led process; can the same objectives be better approached by multiple learning paths; ideally what could be a near perfect mapping between objective(s) and artefact(s); for this to be realised what kind of resources are required; to what extent available resources, if any, are constraining possible learning pathways or even prohibit them; is there any alternative. This step leads to a holistic deep understanding of the goals of an SLE, whose tangible outcome is that the corresponding learning objectives are now prioritised, possible learning products/artefacts are mapped to them, and finally resources needed and activities accompanying them start to emerge. The next step is the pruning and trim of the emerged lush tree of possibilities down to a realistic set of options according to constraints, priorities or circumstances.

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# 5.1 Practical examples

**In the following we discuss two indicative examples that illustrate the different approaches.** They come from the implementation of the pilot SLE entitled "Studying earthquakes" with high-school students in Ellinogermaniki Agogi, Greece.

**In the first case** during co-creation sessions students and teachers brainstormed around the objectives and resources and concluded that the most impactful way to demonstrate the impact of earthquakes in our society is to build seismic shake tables (one of the learning products of this SLE) with easily available materials. Doing so students engaged in iterative cycles of exploring, making and tinkering which encompass also development, practice and advancement in collaboration, innovative thinking and presentation/communication skills. Furthermore, using the same materials and process they devised workshops that can conduct with general audiences in outreach events, science fairs and exhibitions to increase public awareness. The photos shown below highlight relevant work sessions by students.

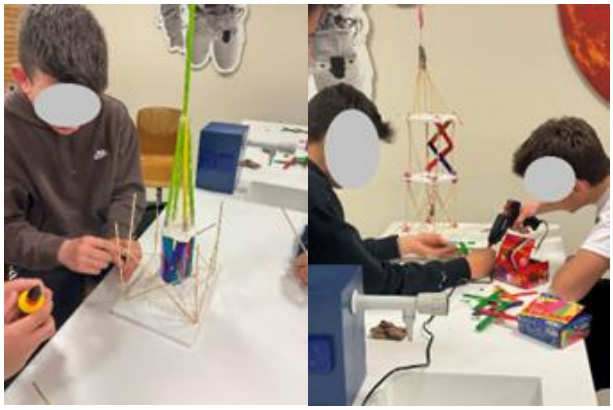

*Figure 1 High school students developing and constructing seismic shake tables with easily accessible materials*

**Regarding the alternative approach** i.e. one to start from the conceptual side or follow a top-down perspective, a corresponding example is as follows. Within the context of the same pilot SLE with the difference that it is mainly addressed to a select group of students, teachers and expert stakeholders first do a deep analysis of the learning objectives. In a sense they try to conceptually go backwards from the final learning product they have in mind, which is to build a DIY seismometer, and envisage and design a pathway with intermediate learning products and objectives. In this process they identify several important learning outcomes that should be reached by learners, and which will enrich their overall understanding and experience. These are among others: what kind of data a seismometer collects, how these data can be utilized to measure the characteristics of an earthquake, how this can be best demonstrated graphically. It should be emphasized that these learning objectives and corresponding learning products and resources can be achieved independently. Meaning that students acquire the relevant knowledge and put it in practice even if they do not finally succeed to build an operational DIY seismometer which is the very final learning artifact of the SLE. The pictures below show an example of two intermediate learning products with respect to extracting useful information from seismometers' data and utilizing it to locate the epicenter of an earthquake.

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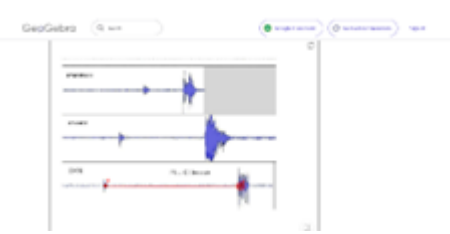

# 6 Assessment of learning products at the end of an SLE

Learning products document learner knowledge and skills, and as such, they can be used for assessment by stakeholders and learners. In open-ended learning environments, students learn by following different paths and with the support of different stakeholders. As a consequences, the assessment of learner engagement should adapt to these differences.

Despite this heterogeneity, learning products can be described during the design phase through standard categories, such as learning scenario, type of learning product, reference material and tools to be used, learning objectives etc. These categories can be useful criteria to validate learning at the end of the SLE, but they should not become an authoritative device to be imposed outside the SLE, though. In this regard, actual learner engagement should be used to update and enlighten the categories and showcase the innovative potential of stakeholders' and learners' communities of practice in SLEs.

To this approach we can add multiple forms that may be employed to assess learning in SLEs based on learning products. For instance, self-assessment and peer assessment on top of expert-teacher assessment, formative assessment on top of summative assessment, portfolio-based assessment on top of scale-based assessment (see Hovardas et al., 2014; Hovardas, 2016a; Vakkou et al., 2023).

Assessment outcomes need to be considered by both learners (to optimize learning paths and outcomes) and stakeholders (to better design learning routes and support learners). A qualitative scheme of assessment of learning products should relate to time needed for their construction or optimization (e.g., if the learning activity and related time devoted to deliver learning products needs to be iterated to optimize them or if optimization is possible with few adjustments/edits).

# 7 Saving and sharing learning products

## 7.1 photographs of products

Each learning product should be documented and uploaded following the instructions at paragraph 7.2. To document individual work, take a photo of each students' work, or of the product resulting from group work. For example, if the learning product consists of a sketch or

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a prototype, each student's sketch and prototype should be uploaded in the same folder. If the product is a unique database, or a mosaic, take a photo of that.

By the end of your experience, you will have to compile a learning scenario, with an updated explanation of the activities you conducted in your SLE. When uploading the photos of the learning artefacts make sure they can be easily traced back to the activities, reported in the learning scenarios, that led to the artefacts creation.

If, for example, an activity consisted in preparing a table to analyse the data of the seismographer, and it was preceded by students trying different methodologies or software, your photos should include also the previous tries, that were then scrapped before making the final decision. So, together with the final product, try to also include the iterations and steps that led to it.

All photos should be in focus and represent clearly the work that was conducted by students.

## 7.2 drives and links

All learning products should be saved anonymously. For each of the activities you conducted, which led to the creation of learning artefacts, you should create a folder and upload the pictures. Each folder should be numbered in the same order in which activities presented in the Overview file (Excel with all activities implemented).

# 8 Privacy issues

SLE initiators and teachers should be careful to document and store learning products while respecting students' privacy. To avoid any risk of GDPR infringement, **no students' personal data should be reported**. Personal data can be:

- First name and last name
- Email address
- Birth date
- Address
- Photos / audio / video
- Phone number
- Gender

Photos, audio or videos should obscure students' faces with an emoticon or any other effective expedient, and voices should be modified to be rendered unrecognizable.

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# 9 References

de Jong,T., Gillet, D., Rodríguez-Triana, M. J., Hovardas, T., Dikke, D., Doran, R., Dziabenko, O., Koslowsky, J., Korventausta, M., Law, E., Pedaste, M., Tasiopoulou, E., Vidal, G., & Zacharia, Z. C. (2021). Understanding teacher design practices for digital inquiry–based science learning: The case of Go-Lab. Educational Technology Research & Development, https://doi.org/10.1007/s11423-020-09904-z.

Efstathiou, C., Hovardas, T., Xenofontos, N., Zacharia, Z., de Jong, T., Anjewierden, A., & van Riesen S. A. N. (2018). Providing guidance in virtual lab experimentation: The case of an experiment design tool. Educational Technology Research & Development, 66, 767–791. https://doi.org/10.1007/s11423-018-9576-z.

European Commission. (2019). Key competences for lifelong learning. Luxembourg: Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/297a33c8-a1f3-11e9-9d01-01aa75ed71a1/language-en. Accessed on 24 July 2024.

Hovardas, T. (2016a). A learning progression should address regression: Insights from developing non-linear reasoning in ecology. Journal of Research in Science Teaching, 53, 1447-1470. https://doi.org/10.1002/tea.21330.

Hovardas, T. (2016b). Primary school teachers and outdoor education: Varying levels of teacher leadership in informal networks of peers. The Journal of Environmental Education, 47, 237-254. https://doi.org/10.1080/00958964.2015.1113155.

Hovardas, T., Tsivitanidou, O. E., Zacharia, Z. (2014). Peer versus expert feedback: Investigating the quality of peer feedback among secondary school students assessing each other's science web-portfolios. Computers & Education, 71, 133 - 152. https://doi.org/10.1016/j.compedu.2013.09.019.

Hovardas, T., Pedaste, M., Zacharia, Z., & de Jong, T. (2018). Model-based science inquiry in computer-supported learning environments: The case of Go-Lab In: A. K. M. Azad, M. Auer, A. Edwards, & T. de Jong (Eds.), Cyber-physical laboratories in engineering and science education (pp. 241-268). Springer, Dordrecht. https://doi.org/10.1007/978-3-319-76935-6_10.

Hovardas, T., Zacharia, Z. C., Xenofontos, N., & de Jong, T. (2022). How many words are enough? Investigating the effect of different configurations of a software scaffold for formulating scientific hypotheses in inquiry oriented contexts. Instructional Science, 50, 361-390. https://doi.org/10.1007/s11251-022-09580-x.

Hovardas, T., Ter Vrugte, J., Zacharia, Z. C., & de Jong, T. (2023). Simulations and games for learning. International Encyclopedia of Education, 4th Edition, 681-688. https://doi.org/10.1016/B978-0-12-818630-5.14074-6.

Vakkou, K., Hovardas, T., Xenofontos, N., & Zacharia, Z. (2023). Comparing expert and peer assessment of pedagogical design in integrated STEAM education. In: O. Noroozi, & B. de

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Wever (Eds.), The power of peer learning - Social Interaction in Learning and Development (121-141). Springer: Cham. https://doi.org/10.1007/978-3-031-29411-2_6.

Xenofontos, N., Hovardas, T., Zacharia, Z. C., & de Jong, T. (2020). Inquiry-based learning and retrospective action: Problematizing student work in a computer-supported learning environment. Journal of Computer Assisted Learning, 36, 12-28. https://doi.org/10.1111/jcal.12384.

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