STEAM LEARNING ECOLOGIES

LEARNER ENGAGEMENT EVALUATION REPORT

Deliverable 4.3

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

D4.3 Learner engagement evaluation report			
Work Package	WP4 Learner Engagement in SLEs		
Lead Partner	University of Cyprus (UCY)		
Author(s)	Tasos Hovardas (UCY), & Kyriaki Vakkou (UCY)		
Due date	30/09/2025 (M33)		
Submitted date	30/09/2025		
Version number	0.1	Status	Final

Project Information	
Project number	101094648
Start date	01/01/2023
Duration	36
Call identifier	HORIZON-WIDERA-2022-ERA-01-70
Type of Action	HORIZON-CSA

Dissemination Level	
PU: Public	☒
PP: Restricted to other programme participants (including the European Commission)	☐
RE: Restricted to a group specified by the consortium (including the European Commission)	☐
CO: Confidential, only for members of the consortium (including the European Commission)	☐

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Quality Control	
Reviewed by:	**Review date:**
Georgios Mavromanolakis (EA)	08/09/2025
<Reviewer 2 name and surname (PARTNER_SHORTNAME)>	<DD/MM/YYYY>

Revision history		
Version	**Date**	**Description**
0.0	03/09/2025	First draft
0.1	18/09/2025	Post-review version

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Executive Summary

The aim of this deliverable is to evaluate learner engagement in STE(A)M Learning Ecologies. We used documentation delivered by national coordinators and stakeholders in the pilot phase and mature phases of the project, as well as learning products delivered by learners to develop and validate a typology of STE(A)M Learning Ecologies. This included participatory pedagogical designs, participatory scenarios, interviews, and questionnaires, as well as the tangible outputs of learning activities in which learners were engaged (learning products). The data to be presented were collected from 12 STE(A)M Learning Ecologies in the pilot phase and another 100 STE(A)M Learning Ecologies in the mature phase of the project, engaging, altogether, more than 4000 learners and more than 500 stakeholders.

There were four different types of STE(A)M Learning Ecologies identified: learner-experience oriented SLEs, master-product oriented SLEs, end-user oriented SLEs, and citizen-science oriented SLEs. The typology revealed characteristic features of SLE types in terms of stakeholder synthesis, learning resources arranged along learning paths, sequencing of learning activities, learning products expected to be delivered by learners, flexibility in pedagogical design, and trade-offs for stakeholder reengagement and learner engagement. Additional features for SLE types were also highlighted, for instance, education level, learning objectives, challenges encountered, and sustainability aspects.

For the entire sample of STE(A)M Learning Ecologies, analysis showed that increase in the number of stakeholders involved is expected to also increase the number and type of learning products, and the latter are also anticipated to increase the number of subjects addressed. These findings underline the transformative character of STE(A)M Learning Ecologies in terms of provision of learning resources and learner support by the stakeholder coalition backing each STE(A)M Learning Ecology. It also points towards the relation between diversity in STE(A)M Learning Ecology outputs (key learning products) and diversity of learning objectives and pedagogical design (subjects addressed), which is crucial for promoting and securing a high degree of interdisciplinarity in STE(A)M Learning Ecologies.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table of contents

List of tables

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

List of figures

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

1. Rationale and scope of the deliverable

Open-ended learning environments like those encountered in open schooling projects are characterized by a rich diversity of approaches in terms of learner engagement. Learners may use a variety of learning resources to enact several learning activities and create learning products (LPs), i.e. artifacts constructed by learners themselves along learning paths in SLEs. Within the frame of the SLEs project, we concentrated on LPs to evaluate learner engagement. These tangible deliverables, physical or digital, which learners construct using tools, while enacting learning activities, offer a unique solution for aligning pedagogical design (e.g., stakeholder engagement for identifying learning resources to be provided to learners and arrangement of these resources along learning paths), implementation (e.g., support to be provided to learners by teachers and stakeholders so that learners will be able to deliver the expected LPs), and assessment (e.g., evaluating if learning objectives have been met and up to which degree).

At this point, we need to highlight that sequencing of learning activities may vary from one context to another, while flexibility in pedagogical design may showcase both the limits as well as the potential of SLEs to expand and engage more stakeholders. Trade-offs can delineate dimensions of pedagogical design where both stakeholders and learners in SLEs may need to find compromises and strike a delicate balance between contradictory needs. All these aspects were taken into account in this report and the analysis of SLEs in two phases of the SLEs project: (1) The pilot phase, where we focused on a rather limited number of pilot SLEs to delineate their basic characteristics and our expectations from learner engagement in SLEs, which included female engagement, career prospects, and sustainability challenges; (2) the mature phase, where many more SLEs were established, implemented, and analysed. This deliverable will conclude with some core findings and recommendations for designing, implementing and assessing open schooling projects to optimize learner engagement.

2. Methodology

For the pilot phase, we used the templates on participatory pedagogical design (Appendix 1), which have been delivered by National Coordinators (Task 4.1 - Learning paths through SLEs), together with LPs in pilot SLEs. Using these materials, we developed a typology of 12 pilot SLEs based on several aspects of learner engagement, for instance, learning paths including learning resources and LPs, sequencing of learning activities, flexibility in pedagogical design, and trade-offs. Analysis included first a thorough read of the entire corpus and a coding process was followed, where initial categories were reconsidered and refined as new SLEs examples were processed. Although we acknowledge that this typology may not be exhaustive, meaning that it could be enriched by accumulating SLEs in the mature phase of the project, it still provides a much-needed guidance for stakeholder and learners to navigate through open schooling projects.

All items delivered for documenting pilot SLEs were used as data sources for outlining characteristic features of SLEs. Apart from participatory pedagogical design templates and LPs, items included

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

participatory scenario development templates, stakeholder interviews, and questionnaires completed by national coordinators. The template for participatory scenario development (Appendix 2) elaborated upon stakeholder synthesis and interaction, the learning resources available and learner support. In this case, baseline conditions with no stakeholder involvement were described as business-as-usual scenarios; small-effort scenarios sketched desirable results under minimal stakeholder input. Best-case scenarios portrayed an ideal situation possible under optimal stakeholder input and investment. Stakeholder interviews addressed the local context in each SLE, stakeholders in the SLE and their experience with open schooling, any challenges encountered by stakeholders, the benefits of the SLE and its added value, how stakeholders commented on learner engagement, sustainability of the SLE, and suggestions for improvement. The questionnaire, which was completed by national coordinators, concentrated on learning outcomes, stakeholder support to learners, any arrangement to facilitate female participation, the experiences of teachers, if stakeholders encountered any challenges, and stakeholder interaction and collaboration.

For the mature phase, we employed learning scenarios and LPs of 100 SLEs in 16 different countries (10 from Cyprus, 10 from Germany, 10 from Greece, 11 from Ireland, 1 from Israel, 9 from Italy, 8 from Malta, 1 from North Macedonia, 10 from Norway, 5 from Portugal, 6 from Romania, 7 from Serbia, 1 from Slovakia, 9 from Spain, 1 from Sweden, 1 from Turkey) to validate the SLEs typology developed in the pilot phase. In this case, we also developed a list of metadata for SLEs and LPs.

The list of metadata was created based on the repository of LPs (Learning-Artefacts) and the learning scenarios (WP4_LS_Mature_Phase). National coordinators uploaded all the LPs of each SLE to this file, following the provided guidelines for collection (WP4-SLEs-Pilot-Guidelines-for-collecting-Learning-Products_V2). To generate the metadata file, an Excel sheet was developed in which LPs were coded by UCY, HUB, EA and EUN. The coding section included the following information for each LP:

- SLE title
- Country of implementation
- Education level
- Number of learners involved
- Number of stakeholders
- Subject(s) of the SLE
- STEM strategy criteria of the SLE
- Language of the LP
- Link to LP file
- Link to learning scenario
- Typology of SLE
- Small description of LP
- Learning path progression number
- Type of LP
- Reference material
- Link to tools to be used to construct the LP
- Link to find the LP

Based on this information, another sheet was added to the metadata file, providing information for each SLE derived from the analysis of the LPs. The metadata file is available here: SLEs_Metadata_learning products_FINAL.xlsm.

For both the pilot and mature phases, inter-rater reliability for all coding processes was satisfactory (Cohen's kappa >0.85).

3. Results

3.1 Pilot phase

Typology of STE(A)M Learning Ecologies

Table 1 presents the typology of pilot SLEs. Learner-experience oriented SLEs comprised the majority of pilot SLEs (Germany; Ireland; Italy; Portugal; Romania; Malta). With regard to sequencing of learning activities, SLEs in this category were quite modular because learning activities did not presuppose one another or did not follow any strict serial sequence and could be switched in order. Flexibility in pedagogical design was promoted by the fact that learning activities and LPs might be skipped or new activities might be added without any major impact on the learning path as well as overall learner experience. A trade-off in this type of SLEs, however, was that the addition of new learning activities and products, which could obviously enhance learner experience in the short term, might compromise the coherence of learner engagement and long-term learning outcomes.

A second type of pilot SLEs was master-product oriented SLEs (Slovakia; Spain; Sweden). Here all learner work converged on a master LP, which was delivered at the end of the learning path. This master LP integrated all prior LPs or needed them to be manufactured. Sequencing of LPs was organized around the master-product, which could be presented to audiences external to the SLE, and which could be also utilized to propose and launch further initiatives. Flexibility in pedagogical design built on the fact that prior LPs could be adapted to suit different learning contexts, provided that the overall structure as dictated by the features of the master product was maintained. Trade-offs related to allocation of time and workload between all necessary prior LPs and the master product.

End-user oriented SLEs were the third type of pilot SLEs (Norway; Serbia). In these cases, learners were tasked to deliver a key LP, which addressed end-user needs and desires. To do so, learners followed a number of iterations, which involved a pronounced co-creation dimension in tight interaction with stakeholders. This co-creation process marked the sequencing of learning activities, which unfolded through a product development lifecycle with marked resemblance to iterative engineering design process or analogous approaches, for instance, model-based inquiry. In terms of flexibility, each design in this SLE type was unique in the sense that key products adhered to end-user needs and desires. A major trade-off was that innovation and creativity of learners and end-users needed to be balanced against narrowing down options so that realism and cost-effectiveness was maintained.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

The fourth and last category of pilot SLEs was citizen-science oriented SLEs (Cyprus; Greece). Learners in these SLEs employed a pre-determined methodology of data collection to contribute to a wider process building on such data, which was supported by multiple social actors in multiple locations. As far as the learning activity sequence is concerned, learners first got familiar with the methodology. Then, they collected data, inserted them into a broader repository, analysed these data, and usually concluded with policy implications. Flexibility was added in the pedagogical design by the fact that policy recommendations and initiatives provided further opportunities of stakeholder engagement and extension of the SLE. The trade-offs to be encountered mostly referred to an optimal balance that needed to be found between the rigidity of the methodology, on the one hand, and innovation in terms of policy recommendations and initiatives, on the other.

Characteristics of STE(A)M Learning Ecologies

Characteristics of SLEs are presented in Table 2. With regard to stakeholder synthesis, learner-experience oriented SLEs in the pilot phase had the maximum number of formal and non-formal education providers, while master-product oriented SLEs revealed the minimum number of governmental stakeholders. End-user oriented SLEs engaged most industry partners, while citizen-science oriented SLEs included the maximum number of stakeholder types.

As far as learning objectives are concerned, all types of SLEs aimed to develop 21st century skills (e.g., communication, collaboration, critical thinking, problem solving, creativity, innovation) as well as data analysis and interpretation skills. Learner-experience oriented SLEs could also target digital skills, computational thinking skills, and experimentation skills. End-user oriented SLEs focused on entrepreneurial skills, while citizen-science oriented SLEs concentrated on modelling skills.

The prioritized method for facilitating female participation across SLE types was female role models, which was promoted through engaging female representatives or spokespersons of stakeholders. Overall, stakeholder spokespersons were also recruited for emphasizing career opportunities among three out of four SLE types (learner-experience oriented; master-product oriented; and citizen-science oriented SLEs). In end-user oriented SLEs, career opportunities were particularly pronounced through the iterative co-creation process followed for optimizing the key LP (end-user product).

For all types of SLEs, a major finding was that small-effort scenarios (i.e., small input and resources invested by stakeholders in SLEs) demarcated a departure from business-as-usual (e.g., everyday school practice without stakeholder support for learners). For example, the addition of one stakeholder only in a SLE could denote additional learning resources and additional support offered to learners, which could have a series of snowball positive effects, namely, enriching learning paths and experiences, letting teachers reallocate their time and workload productively, avoiding any overloading. For learner-experience oriented SLEs and master-product oriented SLEs, there was an additional quantitative change from small-effort to best-case scenarios, propelled primarily through growing stakeholder networks. For end-user oriented SLEs and citizen-science oriented SLEs, the transition from small-effort to best-case scenarios was qualitative in nature, based on evolving end-user demand and peer interactions and communities of practice, respectively.

Challenges for establishing and operating SLEs were linked to formal education constraints for learner-experience oriented SLEs and master-product oriented SLEs (e.g., time and curriculum

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

constraints). In end-user oriented SLEs and citizen-science oriented SLEs challenges related to maintaining the stakeholder coalition and network supporting learners.

Sustainability of SLEs was mostly supply-driven in learner-experience oriented SLEs and master-product oriented SLEs, which dependent largely upon the readiness of stakeholders to provide learning resources and support. Sustainability of SLEs was demand-driven in end-user oriented SLEs and citizen-science oriented SLEs. In end-user oriented SLEs, any effective delivery of the key LP (end-user product) was highly probable to trigger additional demand. In citizen-science oriented SLEs, stakeholder and peer networks cooperating productively would wish to prolong or iterate data collection and analysis with germane policy implications.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 1. Typology of pilot STE(A)M Learning Ecologies

	Learner-experience oriented SLEs	Master-product oriented SLEs	End-user oriented SLEs	Citizen-science oriented SLEs
Learning path including learning resources and learning products	Learners deliver a rich portfolio of diverse learning products making use of dedicated learning resources offered by stakeholders in the SLE	Learner work is converging on a master learning product delivered at the end of the learning path, which integrates all prior learning products	Learners follow a number of iterations to deliver a key learning product, which addresses concrete end-user (stakeholder) needs and desires	Learners follow a pre-specified methodology to contribute to data collection supported by multiple social actors in multiple locations
Sequencing of learning activities	SLEs in this category are quite modular, in the sense that learning activities do not follow any strict serial sequence but can be switched in order	Learner engagement serves the creation of the master product, which can be presented to external audiences and utilized for launching further initiatives	Product development lifecycle; marked resemblance with iterative engineering design process and analogous approaches (e.g. model-based inquiry)	Learners get familiarized with the methodology, collect data, insert them into a broader repository, analyse data, and conclude with policy implications
Flexibility in pedagogical design	Learning activities and learning products can be either skipped or added without any major impact on the learning path and overall learner experience	Overall structure dictated by the features of the master product; prior learning products may be adapted to suit different learning settings	Unique designs focused on end-user needs and desires; learners and end-users maintain contact throughout the duration of the SLE to optimize designs	Further opportunities of stakeholder engagement and extension of the SLE in terms of policy recommendations and initiatives
Trade-offs	More learning activities and products may enhance learner experience in the short term at the expense of coherence and long-term learning outcomes	Time and workload for learners and stakeholders needs to be effectively allocated to all necessary prior learning products as well as the master product	Learners and end-users need to be creative and, at the same time, be able to narrow down options to maintain realism and cost-effectiveness	Stakeholders and learners need to strike an optimal balance between the rigidity of the methodology and innovation in terms of policy initiatives
Examples of pilot SLEs	DE; IE; IT; PT; RO; MT	SK; ES	NO; RS	CY; GR

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 2. Similarities and differences between types of STE(A)M Learning Ecologies

	Learner-experience oriented SLEs	Master-product oriented SLEs	End-user oriented SLEs	Citizen-science oriented SLEs
Stakeholder synthesis	Maximum number of formal and non-formal education providers	Minimum number of governmental stakeholders	Maximum number of industry partners	Maximum number of stakeholder types
Learning objectives	21st century skills; data analysis and interpretation skills; digital and/or computational thinking skills and/or experimentation skills	21st century skills; data analysis and interpretation skills	21st century skills; data analysis and interpretation skills; entrepreneurial skills	21st century skills; data analysis and interpretation skills; modelling skills
Female participation	Female role models	Female role models	Female role models	Female role models
Career opportunities	Stakeholder spokespersons	Stakeholder spokespersons	Particularly pronounced through the iterative co-creation process	Stakeholder spokespersons
Change	Transformative change in small-effort scenarios; increasing number of stakeholders increases availability of learning resources and learner support; quantitative change in best-case scenarios	Transformative change in small-effort scenarios; increasing number of stakeholders increases availability of learner support; quantitative change in best-case scenarios	Transformative change in small-effort scenarios; increasing number of stakeholders increases availability of learner support; qualitative change in best-case scenarios	Transformative change in small-effort scenarios; peer interaction increases availability of learning resources and learner support; qualitative change in best-case scenarios
Challenges	Formal education constraints	Formal education constraints	Sustain stakeholder network	Sustain stakeholder network
Sustainability	Supply-driven	Supply-driven	Demand-driven	Demand-driven

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

3.2 Mature phase

The results to be presented for the mature phase of the project include information from 100 SLEs, established and implemented in. A first major task of data analysis in the mature phase was to validate the typology developed in the pilot phase. Using learning scenarios and LPs, we were able to classify all 100 SLEs in one of the four SLE types, which validated the typology. There were 38 learner-experienced oriented SLEs, 35 master-product oriented SLEs, 6 end-user oriented SLEs, and 21 citizen-science oriented SLEs. A considerable majority of SLEs pertained to secondary education and fewer SLEs were established and operated for primary education (Table 3). There were six only SLEs for higher education, which were all end-user oriented SLEs.

Table 3. Number of types of STE(A)M Learning Ecologies per education level

Typology of SLEs	Education level				
	Lower Primary	Upper Primary	Lower Secondary	Upper Secondary	Higher education
Learner-experience oriented SLEs	7	4	18	9	0
Master-product oriented SLEs	3	4	20	10	0
End-user oriented SLEs	0	0	0	0	6
Citizen-science oriented SLEs	1	2	10	11	0

Note: The total number across all education levels exceeds 100 (the total SLEs) because one SLE could include learners from more than one education level.

Differences in the number of learners, stakeholders, stakeholder types, LPs, LP types and subjects between different SLE types were examined using non-parametric tests (Kruskal-Wallis and Mann-Whitney tests). Table 4 presents the results of the analysis. Number of learners differed significantly between SLE types (Kruskal-Wallis H=21.32, $p<0.001$), with learner-experience oriented SLEs revealing the maximum average number of learners, and end-user oriented SLEs the minimum average. Number of learners differed significantly between these two types of SLEs (Mann-Whitney $Z = -3.58$, $p < 0.008$).

The average number of stakeholders followed the same ranking with the average number of learners per SLE type, with learner-experience oriented SLEs ranking highest, followed by citizen-science oriented SLEs, then master-product oriented SLEs and then end-user oriented SLEs. Differences between SLE types were significant (Kruskal-Wallis H=22.36, $p<0.001$), with learner-experience oriented SLEs scoring higher than master-product oriented SLEs (Mann-Whitney $Z = -3.59$, $p < 0.008$), and end-user oriented SLEs (Mann-Whitney $Z = -3.11$, $p < 0.008$). Citizen-science oriented SLEs also scored higher than master-product oriented SLEs (Mann-Whitney $Z = -2.68$, $p < 0.008$) and end-user oriented SLEs (Mann-Whitney $Z = -3.10$, $p < 0.008$). Overall, the number of learners was much more diverse between SLEs than the number of stakeholders, as we can observe when

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

comparing average values to standard deviations (standard deviations are lower than averages for number of stakeholders across all SLE types).

Table 4. Learners, stakeholders, learning products and subjects per type of STE(A)M Learning Ecologies

Typology of SLEs	Number of learners	Number of stakeholders	Number of stakeholder types	Number of LPs	Number of LP types	Number of subjects
Learner-experience oriented SLEs	48.89 (42.95)	5.95 (3.97)	3.00 (1.01)	3.97 (1.90)	2.87 (1.63)	3.18 (1.39)
Master-product oriented SLEs	30.69 (31.48)	3.51 (1.10)	2.74 (0.95)	3.63 (2.06)	2.66 (0.97)	2.60 (1.36)
End-user oriented SLEs	11.50 (4.59)	2.67 (0.52)	2.50 (0.55)	2.83 (0.75)	2.33 (1.03)	2.17 (0.41)
Citizen-science oriented SLEs	34.00 (48.38)	4.62 (1.72)	3.38 (0.87)	5.10 (3.10)	3.10 (1.45)	2.43 (0.81)
Kruskal-Wallis Test statistic	21.32***	22.36***	7.20ns	7.80ns	1.48ns	6.67ns

Note: Average number is presented for each variable and for each type of STE(A)M Learning Ecologies; standard deviations are given in parentheses; ns = non-significant; *p < 0.05; **p < 0.01; ***p <0.001.

Number of stakeholder types, number of LPs, and number of LP types exemplified a different rank order when compared to number of learners and number of stakeholders. Although differences between SLE types were not significant for these variables, there was still a trend that citizen-science SLEs scored higher and end-user oriented SLEs presented lowest values. For the number of subjects, the former ranking was restored with learner-experience oriented SLEs having the maximum value and end-user oriented SLEs revealing the lowest.

We need to note, at this point, that the above results should be taken to denote any unfavorable status of end-user oriented SLEs as compared to learner-experience oriented SLEs in terms of learning outcomes. Although we acknowledge that more work will be needed to delve deeper into learner performance and outputs, we can still discern the heterogeneity of learning paths and flow of learning activities in different types of SLEs. For instance, learner-experience oriented SLEs may provide a richness of learner-stakeholder interactions and learning resources. On the other hand, the richness of end-user oriented SLEs is to be sought in the depth of engagement needed to optimize a core LP to be delivered for end-users. Such an insight can be gained when observing the different stakeholder groups interacting with learners in different SLE types (Table 5).

Although learner-experience oriented SLEs presented the highest averages for stakeholders in formal, informal and non-formal education, end-user oriented SLEs had the highest average in the case of civil society and industry partners. These latter stakeholder groups may be the end-users of the optimized LPs in end-user oriented SLEs and their engagement can have important implications for triggering the involvement of civil society actors and industry partners in open schooling projects in STE(A)M, overall. Having said so, we need to highlight the rather low number of end-user oriented SLEs and the fact that they were all from one country (Norway) and pertaining to one education level only (higher education). This would mean that capitalizing on the germane effects of end-user

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

oriented SLEs in K-12, especially the interactions between learners and industry partners, would demand a proper adaptation and transfer of that SLE type to primary and secondary education. A last note with regard to stakeholder type is the highest frequency of governmental stakeholders in citizen-science oriented SLEs, which obviously reflects the policy dimension of the latter SLE type (Table 5).

Table 5. Average number of types of stakeholders per type of STE(A)M Learning Ecologies

Typology of SLEs	Stakeholders					
	Formal education	Informal education	Non formal education	Governmental	Civil society	Industry
Learner-experience oriented SLEs	2.58 (2.91)	0.71 (0.87)	1.42 (1.75)	0.47 (0.69)	0.37 (0.54)	0.39 (0.76)
Master-product oriented SLEs	1.34 (0.68)	0.26 (0.61)	0.71 (0.57)	0.23 (0.60)	0.26 (0.44)	0.71 (0.83)
End-user oriented SLEs	1.00 (0)	0	0	0.33 (0.52)	0.50 (0.55)	0.83 (0.75)
Citizen-science oriented SLEs	1.57 (0.68)	0.05 (0.22)	1.05 (0.74)	1.24 (0.83)	0.38 (0.50)	0.33 (0.48)

Note: Standard deviations are given in parentheses

Table 6 presents Spearman's correlations between the variables examined above. We can observe that the number of learners increases with the number of stakeholders (Spearman's Rho = 0.28, $p < 0.01$). Indeed, it seems that the number of stakeholders presented significant correlations with all other parameters, which indicates the more stakeholders engaged in an SLE the more LPs to be expected, both in number (Spearman's Rho = 0.41, $p < 0.001$) and type (Spearman's Rho = 0.31, $p < 0.01$), and the more subjects to be addressed (Spearman's Rho = 0.25, $p < 0.05$). We also need to highlight the significant correlations between LPs number and type with number of subjects.

Table 6. Spearman's correlations between different characteristics of STE(A)M Learning Ecologies

	Number of stakeholders	Number of stakeholder types	Number of LPs	Number of LP types	Number of subjects
Number of learners	0.28**	0.03ns	0.81ns	0.81ns	0.14ns
Number of stakeholders		0.62***	0.41***	0.31**	0.25*
Number of stakeholder types			0.28**	0.22*	0.08ns
Number of LPs				0.76***	0.45***
Number of LP types					0.44***

Note: N=100; ns = non-significant; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Concerning the types of LPs, the mature phase revealed the considerable creativity potential of SLEs. Table 7 provides the average number of 24 LP types for each category of SLEs.
Physical artefacts, drawings, and experimental designs featured with relatively increased frequency among learner-experience oriented SLEs. For master-product oriented SLEs, physical artefacts, videos, models, texts, and experimental design were the most frequent types of LPs. There were only three types of LPs reported for end-user oriented SLEs, namely, texts, presentations, and software. As we have already noted for end-user oriented SLEs, the low number of LP type should not be taken as a weakness in terms of learner engagement, since this category of SLEs is based on the co-creation of a core product focusing on needs and desires of end users. In addition, the creation of software as a type of LP is especially creative and demonstrates the expectations one can have from this SLE category. An analogous point should be made for tools as a type of LP, which signifies the development of tools as creations derived through learner engagement destined to deliver more creations (i.e., delivering an LP in the form of a tool to create more LPs using this tool). This tool had a relatively high frequency in learner experience oriented SLEs and can be especially exploited for engaging learners in areas which are relatively unexplored yet in open schooling, for instance, engaging learners in technology design and testing such designs with stakeholders.

Citizen-science oriented SLEs delivered mostly presentations, tables, graphs, data sheets, and maps. Overall, we can observe the occurrence of specific LP types in specific SLE types (e.g., physical artefacts delivered in learner-experience oriented SLEs and master-product oriented SLEs but not end-user oriented SLEs of citizen-science oriented SLEs), and LP types which may have an instrumental role for some SLE types (e.g., a video serving as the master LP; a software serving as the core LP to be optimized in an end-user oriented SLE; tables, graphs, data sheets, and maps serving for gathering and analyzing data in citizen-science oriented SLEs as well as guiding discussion with stakeholders in this same type of SLEs.

Selected examples of learning products are presented in the figures below.

Funded by the European Union

This project is funded by the European Union’s Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 7. Average number of learning product type per type of STE(A)M Learning Ecologies

Typology of SLEs	LPs type											
	Physical artefact	Audio	Concept map	Data sheet	Drawing	Experimental designs	Flow diagram	Graph	Guide	Image	Map	Model
Learner-experience oriented SLEs	0.61 (0.79)	0.03 (0.16)	0.11 (0.31)	0.32 (0.70)	0.50 (0.86)	0.50 (0.86)	0.03 (0.16)	0.16 (0.59)	0.03 (0.16)	0.03 (0.16)	0.03 (0.16)	0.37 (0.75)
Master-product oriented SLEs	0.37 (0.88)	0.03 (0.17)	0.06 (0.24)	0.17 (0.45)	0.21 (0.93)	0.31 (0.93)	0.20 (0.53)	0	0.03 (0.17)	0.14 (0.49)	0.03 (0.17)	0.34 (0.77)
End-user oriented SLEs	0	0	0	0	0	0	0	0	0	0	0	0
Citizen-science oriented SLEs	0	0	0	0.43 (0.51)	0	0	0.05 (0.22)	0.52 (1.17)	0	0.33 (0.48)	0.43 (0.93)	0.14 (0.36)

Note: Standard deviations are given in parentheses

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 7a. Continued

Typology of SLEs	LPs type											
	Poster	Presentation	Role play	Screenshot	Script	Simulation	Software	Table	Text	Tool	Video	Website
Learner-experience oriented SLEs	0.32 (0.47)	0.16 (0.44)	0.05 (0.32)	0.30 (0.16)	0	0.03 (0.16)	0	0.13 (0.34)	0.39 (0.86)	0.13 (0.41)	0.05 (0.23)	0
Master-product oriented SLEs	0.14 (0.36)	0.20 (0.76)	0.03 (0.17)	0.09 (0.37)	0.26 (0.44)	0.09 (0.37)	0	0.09 (0.28)	0.34 (0.68)	0.06 (0.34)	0.37 (0.55)	0.03 (0.17)
End-user oriented SLEs	0	0.83 (0.75)	0	0	0	0	0.67 (0.52)	0	1.33 (0.52)	0	0	0
Citizen-science oriented SLEs	0.10 (0.44)	1.52 (1.78)	0	0.24 (0.54)	0	0.24 (0.54)	0	0.57 (1.25)	0.29 (0.56)	0.05 (0.22)	0.14 (0.36)	0

Note: Standard deviations are given in parentheses

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Figure 1. 3D model of a bowl designed by students in the Master-product oriented SLE titled "Digital creativity and entrepreneurship" (Greece)

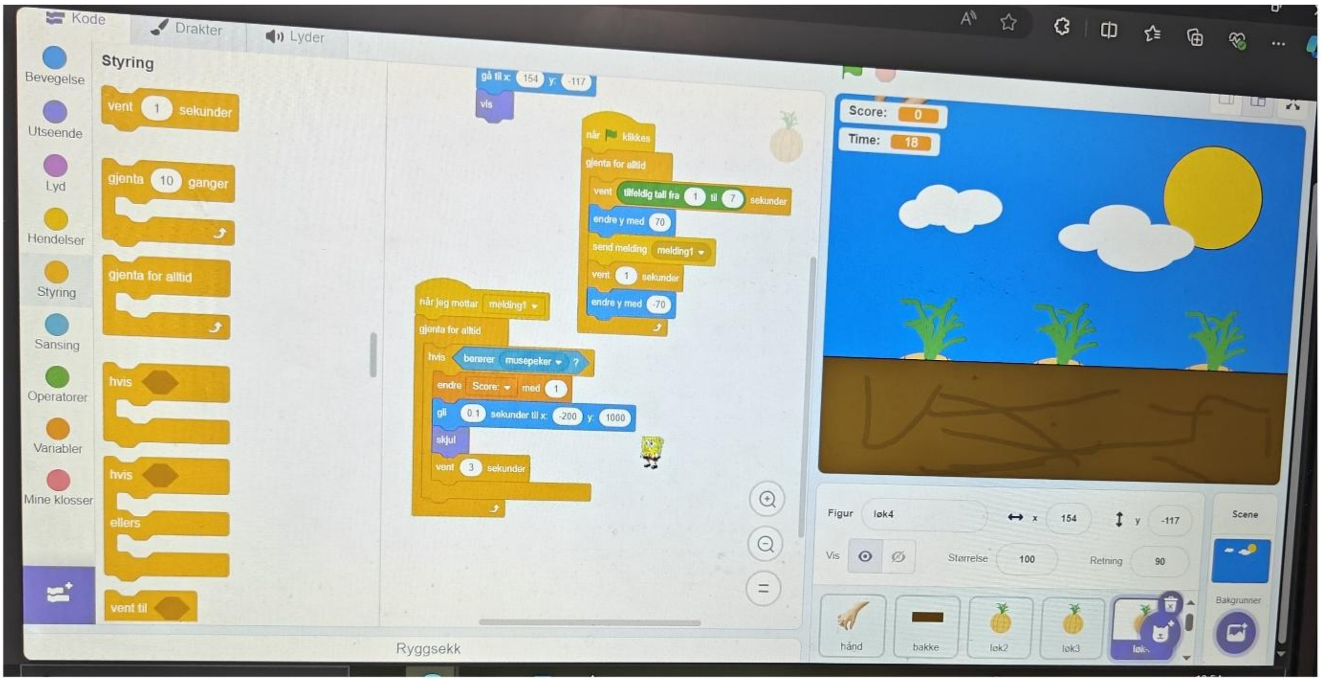
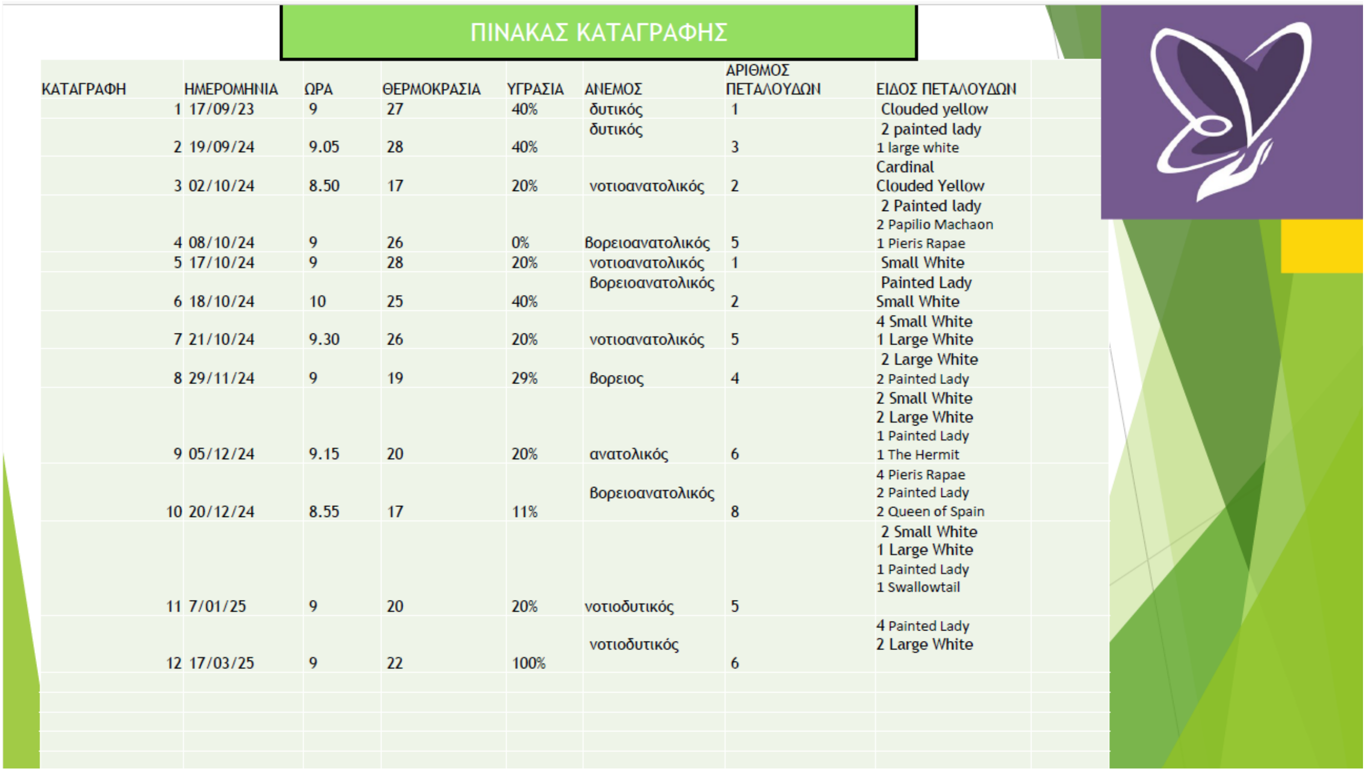


Figure 2. Flow diagram (center) representing the logic and structure of the game, and simulation (right) developed to test and interact with the game — both created by students in the Master-product oriented SLE 'Game Development (Norway)

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.



ΠΙΝΑΚΑΣ ΚΑΤΑΓΡΑΦΗΣ

ΚΑΤΑΓΡΑΦΗ	ΗΜΕΡΟΜΗΝΙΑ	ΩΡΑ	ΘΕΡΜΟΚΡΑΣΙΑ	ΥΓΡΑΣΙΑ	ΑΝΕΜΟΣ	ΑΡΙΘΜΟΣ ΠΕΤΑΛΟΥΔΩΝ	ΕΙΔΟΣ ΠΕΤΑΛΟΥΔΩΝ
1	17/09/23	9	27	40%	δυτικός	1	Clouded yellow
2	19/09/24	9.05	28	40%	δυτικός	3	2 painted lady 1 large white
3	02/10/24	8.50	17	20%	νοτιοανατολικός	2	Cardinal Clouded Yellow
4	08/10/24	9	26	0%	Βορειοανατολικός	5	2 Painted lady 2 Papilio Machaon 1 Pieris Rapae
5	17/10/24	9	28	20%	νοτιοανατολικός	1	Small White
6	18/10/24	10	25	40%	Βορειοανατολικός	2	Painted Lady Small White
7	21/10/24	9.30	26	20%	νοτιοανατολικός	5	4 Small White 1 Large White
8	29/11/24	9	19	29%	Βορειος	4	2 Large White 2 Painted Lady
9	05/12/24	9.15	20	20%	ανατολικός	6	2 Small White 2 Large White 1 Painted Lady 1 The Hermit
10	20/12/24	8.55	17	11%	Βορειοανατολικός	8	4 Pieris Rapae 2 Painted Lady 2 Queen of Spain
11	7/01/25	9	20	20%	νοτιοδυτικός	5	2 Small White 1 Large White 1 Painted Lady 1 Swallowtail
12	17/03/25	9	22	100%	νοτιοδυτικός	6	4 Painted Lady 2 Large White

Figure 3. Data sheet of butterflies records in the Citizen-science oriented SLE titled “Butterfly project 3” (Cyprus)

Figure 4. Posters for promoting clean beaches in the Learner-experience oriented SLE titled “Maths Camp – Our Heritage through Maths” (Malta)

Funded by the European Union

This project is funded by the European Union’s Horizon programme under grant agreement No 101094648. Views and opinions are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

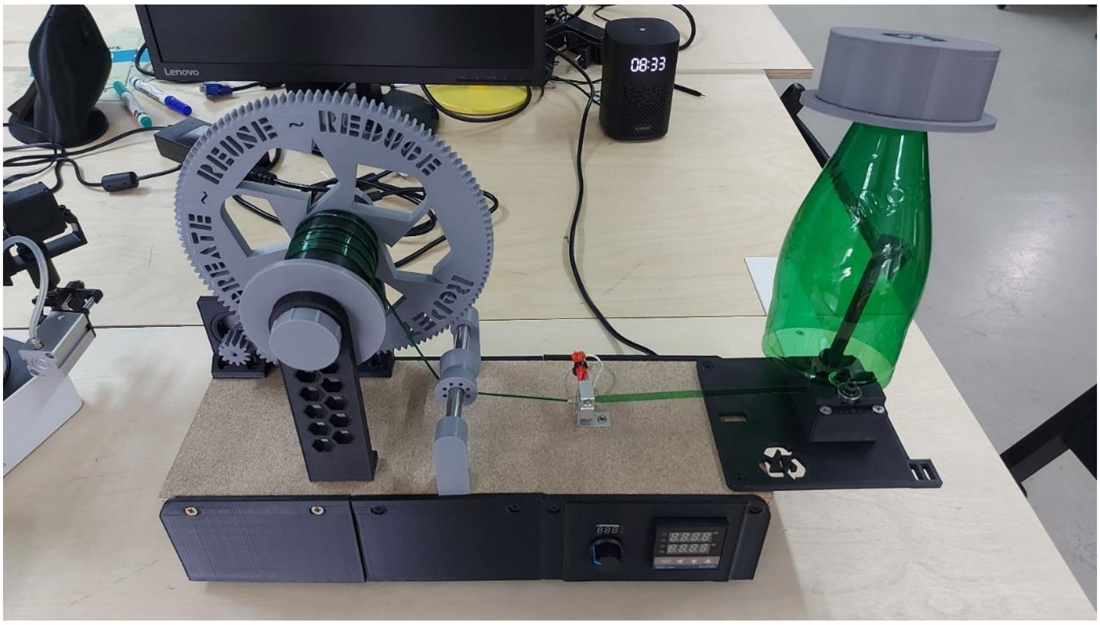
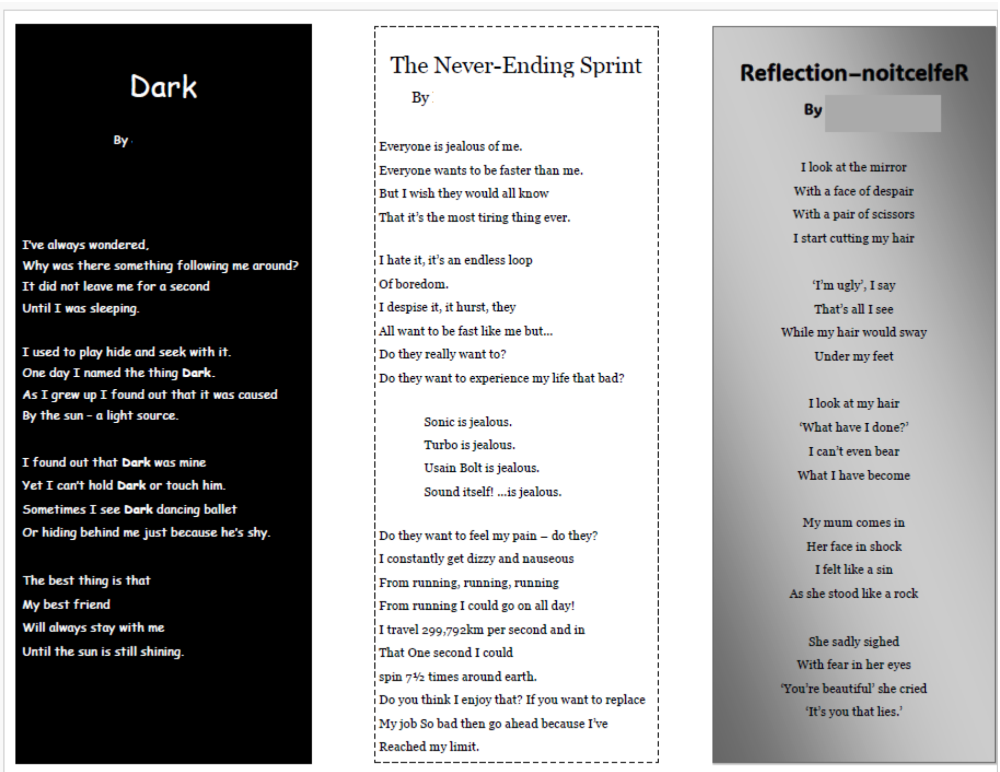


Figure 5. Device (tool) that processes plastic bottles into filament for 3D printers in the Learner-experience oriented SLEs titled "Smart recycling: From plastic bottle to 3D printing"



Dark

By

I've always wondered,
Why was there something following me around?
It did not leave me for a second
Until I was sleeping.

I used to play hide and seek with it.
One day I named the thing **Dark**.
As I grew up I found out that it was caused
By the sun - a light source.

I found out that **Dark** was mine
Yet I can't hold **Dark** or touch him.
Sometimes I see **Dark** dancing ballet
Or hiding behind me just because he's shy.

The best thing is that
My best friend
Will always stay with me
Until the sun is still shining.

The Never-Ending Sprint

By

Everyone is jealous of me.
Everyone wants to be faster than me.
But I wish they would all know
That it's the most tiring thing ever.

I hate it, it's an endless loop
Of boredom.
I despise it, it hurst, they
All want to be fast like me but...
Do they really want to?
Do they want to experience my life that bad?

Sonic is jealous.
Turbo is jealous.
Usain Bolt is jealous.
Sound itself! ...is jealous.

Do they want to feel my pain – do they?
I constantly get dizzy and nauseous
From running, running, running
From running I could go on all day!
I travel 299,792km per second and in
That One second I could
spin 7½ times around earth.
Do you think I enjoy that? If you want to replace
My job So bad then go ahead because I've
Reached my limit.

Reflection–noitcelfeR

By

I look at the mirror
With a face of despair
With a pair of scissors
I start cutting my hair

'I'm ugly', I say
That's all I see
While my hair would sway
Under my feet

I look at my hair
'What have I done?'
I can't even bear
What I have become

My mum comes in
Her face in shock
I felt like a sin
As she stood like a rock

She sadly sighed
With fear in her eyes
'You're beautiful' she cried
'It's you that lies.'

Figure 6. Text represents poems inspired by the theme of light in the Learner-experience oriented SLE titled: Luminous (Malta)

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Figure 7. Cards and bookmarks (artefacts) made from recycled paper in the Master-product oriented SLE titled: Paper with a purpose: recycling, creativity, and social responsibility (Serbia)

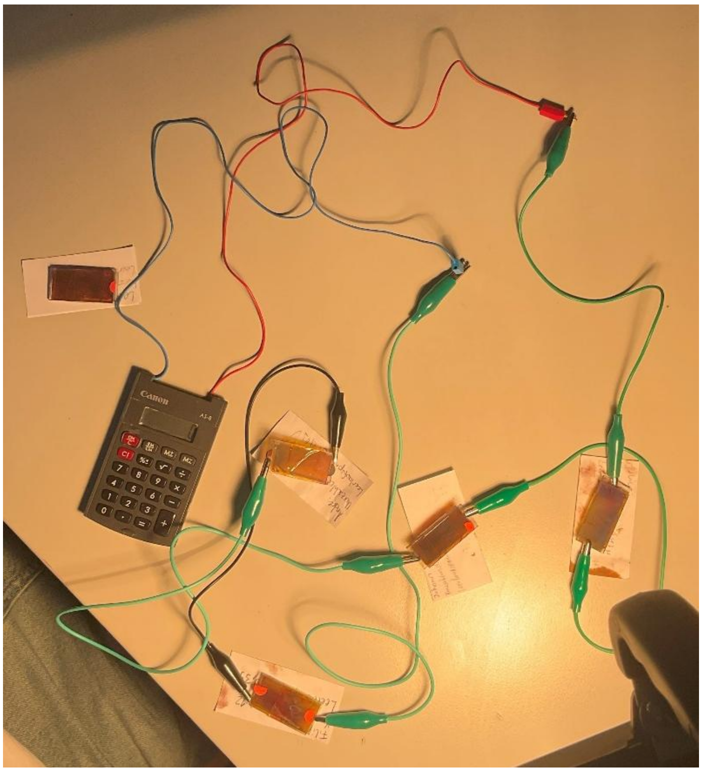


Figure 8. Experimental design operating a calculator with self-built solar cells in the Master-product oriented SLE titled: Project day on solar energy (Germany)

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

With regard to subjects addressed by different types of SLEs, there were, overall, 27 different subjects identified in SLEs learning scenarios (Table 8). Biology and environmental science were quite salient in learner-experience oriented SLEs, master-product oriented SLEs, and citizen-science oriented SLEs. Technology had the highest rank in master-product oriented SLEs, while end-user oriented SLEs concentrated on computer science.

We run a final multivariate analysis in SPSS (tree modeling) using all parameters presented above as independent variables for classifying SLEs in the four different SLE categories of the typology (dependent variable). We used the Classification and Regression Trees (CRT) method for growing the tree. The output of the analysis is presented in Figure 9.

At the top of the tree, the figure displays the different SLE types. At each split, the independent variable that defined that split is listed together with the values of this independent variable, which determine the allocation of SLEs into left or right branches of the tree. All end nodes, namely, nodes where classification is terminated, provide the number of SLEs in each category of the typology.

In the first split of the tree, the subject of computer science transfers on the right half of the tree all six end-user oriented SLEs, which are then included in the second split in an end node on the right branch defined by higher education as an education level ("> upper secondary education"; Node 6). SLEs of other education levels on this half of tree, with less than 22 learners, were most probably citizen-science oriented SLEs (next split, left branch; Node 11). SLEs with more than 22 learners and less than 3 types of LP were definitely master-product oriented SLEs (Node 15); if they had more than 3 LP types, they were most likely learner experienced oriented SLEs (Node 16).

Returning up in the first split of the tree, those SLEs, which did not focus on computer science, but involved videos as an LP type (left half of the tree, second split, right branch) and engaged less than 62 learners (third split) were definitely master-product oriented SLEs (Node 9). SLEs not focusing on computer science and not delivering any videos, were learner-experience oriented SLEs when they engaged more than 7 stakeholders (left half of the tree, Node 8). SLEs with fewer than 7 stakeholders and no non-formal education stakeholder were most probably learner-experienced oriented SLEs, if they engaged more than 15 learners (Node 18). Presence of non-formal education stakeholders combined with absence of governmental stakeholders resulted most likely in master-product oriented SLEs.

The tree, overall, classified correctly 80% of all SLEs using as independent variables the subject of computer science, education level, number of LP types, videos as an LP type, number of stakeholders, number of learners, as well as presence or absence of non-formal education stakeholders and governmental stakeholders (8 independent variables).

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 8. Number of subjects per type of STE(A)M Learning Ecologies

Typology of SLEs	Subjects														
	Applied Sciences	Astronomy	Biochemistry	Biology	Biotechnology	Botany	Carrer Education	Chemistry	Computer Science	Ecology	Energy	Engineering	Environmental science	Food technology	Geography
Learner-experience oriented SLEs	4	2	1	19	0	1	2	11	3	5	0	4	17	0	1
Master-product oriented SLEs	1	0	1	11	2	1	1	7	6	4	0	2	9	2	1
End-user oriented SLEs	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
Citizen-science oriented SLEs	2	0	0	13	0	0	0	3	13	0	1	1	7	0	2

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Table 8a. Continued

Typology of SLEs	Subjects											
	Geology	Information and communication technology	Marine sciences	Materials	Mathematics	Medicine	Pharmaceutics	Physics	Software	Space exploration	Technology	Zoology
Learner-experience oriented SLEs	7	5	2	3	9	7	2	7	0	0	8	1
Master-product oriented SLEs	2	6	2	2	8	4	0	4	1	1	13	0
End-user oriented SLEs	0	3	0	0	0	0	0	0	4	0	0	0
Citizen-science oriented SLEs	1	3	0	0	1	0	0	0	0	0	4	0

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

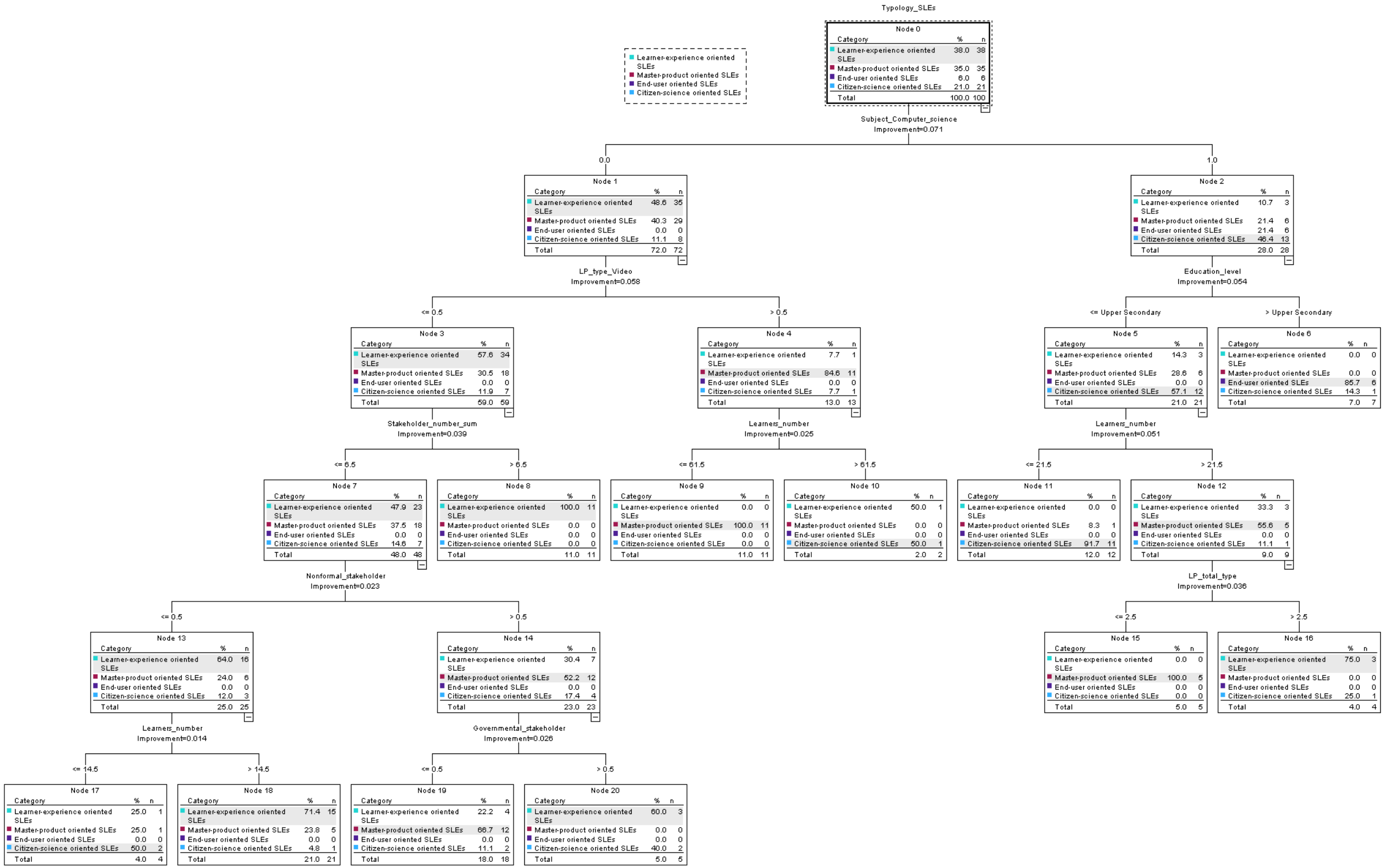


Figure 9. Tree model depicting parameters which are decisive for classifying STE(A)M Learning Ecologies into the categories of the typology (dependent variable displayed at the top of the tree).

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

4. Discussion and implications of the main findings

Using the documentation for each SLE, we were able to develop a typology of SLEs in the pilot phase of the project, which was validated in the mature phase. There were clear patterns of how learning resources were arranged into learning paths, how key LPs were expected in the flow of learning activities, which degrees for flexibility were available in participatory pedagogical designs, and which trade-offs featured in each SLE type. The four types of SLEs were: (1) Learner-experience oriented SLEs; (2) master-product oriented SLEs; (3) end-user oriented SLEs; and (4) citizen-science oriented SLEs. Different types of SLEs displayed different features, with considerable implications for launching and sustaining open schooling projects focusing on STE(A)M.

Apart from characteristics of SLEs shared across all types (e.g., pursuing the development of 21st century skills, data analysis and interpretation skills; promoting female participation through female role models sought in stakeholder representatives and spokespersons; opting for transformative change in small-effort scenarios), there were some features which grouped learner-experience oriented SLEs together with master product oriented SLEs, for example, formal education constraints and supply-driven sustainability, while other features grouped end-user oriented SLEs with citizen-science oriented SLEs, for instance, the challenge of sustaining stakeholder networks and a demand-driven sustainability.

The above groupings would denote that end-user oriented SLEs and citizen-science oriented SLEs could be much more suited for scaling up open schooling projects concentrated on STE(A)M, primarily, their demand-driven sustainability. The mature phase of our project, however, showcased how end-user oriented SLEs were all confined to higher education, while citizen-science oriented SLEs were much more numerous in secondary education as compared to primary education. Given these findings, policy makers and other stakeholders could consider how to implement end-user oriented SLEs in lower education levels, and how to increase the frequency of citizen-science oriented SLEs in primary education.

Each SLE type displayed specific characteristics, which adhered to a combination of stakeholder synthesis, stakeholder interaction, learning path, and expected delivery of LPs. Learner-experience oriented SLEs engaged the highest number of formal, informal, and non-formal education providers, which reflected their potential to attract a considerable number of stakeholders from the wider educational community. End-user oriented SLEs involved the highest number of civil society stakeholders and industry partners as consumers of the key LP they delivered (end-user product). Citizen-science oriented SLEs had the highest number of governmental stakeholders, who were engaged in the policy cycle initiated by data collection and analysis in this type of SLE. The latter category of SLEs was, furthermore, the most heterogeneous one in terms of number of stakeholder types and number of LP types.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

For the entire sample of SLEs, correlational analysis showed that increase in the number of stakeholders involved in a SLE is expected to also increase number and type of LPs, and the latter are also anticipated to increase the number of subjects addressed. These findings underline the transformative character of SLEs in terms of provision of learning resources and learner support by the stakeholder coalition backing each SLE. It also points towards the relation between diversity in SLE outputs (key LPs) and diversity of learning objectives and pedagogical design (subjects addressed), which is crucial for promoting and securing a high degree of interdisciplinarity in SLEs.

Biology and environmental sciences featured as the most frequent subjects addressed across SLE types, which reveals that these two subjects may function as attractors for initiating or relaunching open schooling projects focusing on STE(A)M. To a lesser extent, technology and computer science were also found to organize pedagogical design in SLEs, the former in master-product oriented SLEs, the latter in end-user oriented SLEs. These subjects should be prioritized for peer interaction and collaboration in teacher professional development programmes concentrated on open schooling. The same subjects can also guide school principals and stakeholders in educational leadership for promoting open schooling.

The multivariate analysis we computed in the form of tree modelling revealed how a subset of 8 only variables, representing most variable categories examined in this deliverable, was able to reconstruct the SLE typology and classify correctly 80% of all SLEs. This was another validation of the typology and its potential to support SLEs in the future. In this regard, the different features which are characteristics for each SLE category, can guides stakeholder interaction for providing SLE type-specific support to learners and let stakeholder recruit the proper learning resources and arrange them adequately. To this end, metadata of SLEs and LPs can prove decisive.

Future projects should delve deeper into details of metadata of LPs so that we can better understand and monitor learner engagement and performance in SLEs. Metadata describing tangible outputs of learning activities in open schooling projects focusing on STE(A)M would enable elaborate statistical analyses, for instance, lag sequential analysis, so that we can track learner actions along their learning paths and describe how LPs are sequenced in time. In this way, we could determine which aspects of which LPs are decisive for increasing or decreasing the odds of other LPs to emerge at a later point in time. All this info could be transferred to AI tutors aiming to support learner trajectories through the provision of learner-tailored feedback.

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

5. Appendices

5.1 Appendix 1. Template for participatory pedagogical design

Main themes for participatory pedagogical design	Tasks	Examples
(1) Learning products to be created by students themselves along learning paths	Please describe artefacts that are expected by learners in the above learning sequence; can you please give texts, graphs, drawings, sketches, demos, mockups, etc., for these learning products?	Any artefact that will be created by learners during enacting learning activities, e.g., texts, graphs, models, digital artefacts, and any other product manufactured by learners using learning resources.
(2) Potential learning paths; how learning resources can be arranged to form learning paths	Please describe the sequence of learning activities in the SLE pilot. Which learning resources are necessary for these learning activities? Is there one path to take only or can learners have alternative learning paths? Please explain.	Which learning products are expected first and which next? Is any learning product necessary for creating another learning product in the learning activity sequence?
(3) Curriculum mapping of knowledge and skills	Which targeted knowledge and skills are	Correspondence of knowledge and skills

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Main themes for participatory pedagogical design	Tasks	Examples
as reflected by learning products	reflected in these learning products? Please match knowledge and skills reflected in these learning products to curriculum standards	reflected by learning products to curriculum standards for corresponding subjects
(4) Support and guidance to be provided by stakeholders to students along learning paths	Please describe how stakeholders can guide and support students while using learning resources to enact learning activities	E.g., Elaborate on the usability of certain apps; scaffold data collection and analysis
(5) Opportunities for female engagement	Please describe how the learning path may attract both males and females	E.g., Selection of topics; female representatives or spokespersons acting as role models
(6) Career opportunities	Please describe how stakeholders involved in the SLE pilot can inspire learners' career paths	E.g., Career opportunities promoted through stakeholder representatives in key positions (public, private, and civil society organizations)

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

5.1 Appendix 2. Participatory scenario development for the Butterfly project (CY)

	Business-as-usual scenario (Baseline conditions, crucial gaps and inconsistencies to address when implementing SLEs)	**Small-effort scenario (Small-scale inputs potentially decisive for achieving considerable progress in the short-term)**	**Best-case scenario (Ideal conditions for SLEs to flourish and secure long-term sustainability)**
Stakeholder synthesis	The Butterfly project is part of a European initiative which employs the same methodology to gather and analyze butterfly data from multiple European locations. In Cyprus, the project was initiated by the Ministry of Education, Sport and Youth (Unit for Education for the Environment and Sustainable Development) under the support of the Open University of Cyprus. A secondary school teacher in a school near Nicosia adopted it from a colleague of hers.	The University of Cyprus (Research in Science and Technology Education Group) joined the project as National Coordinator in the SLEs project and the Butterfly project was the pilot SLE selected in Cyprus. Additional stakeholders, which joined the stakeholder coalition, are the Local Municipality of Pera Chorio and the Museum of Natural History in Dali, which hosts an exhibition of the butterfly project.	Other stakeholders sought to join the network and foster its strengths and sustainability were: (1) The Department of Forests in Cyprus, which may adopt student recommendations to enhance flora and butterfly diversity and support butterfly pollination; (2) firms offering gardener services in the wider area of Nicosia may provide additional learning resources and integrate student recommendations in their business model.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

	Business-as-usual scenario (Baseline conditions, crucial gaps and inconsistencies to address when implementing SLEs)	Small-effort scenario (Small-scale inputs potentially decisive for achieving considerable progress in the short-term)	Best-case scenario (Ideal conditions for SLEs to flourish and secure long-term sustainability)
Stakeholder interaction	The teacher tries to bring additional stakeholders in the project through personal initiatives and interpersonal relationships, which is restricted by time constraints, lack of resources, and total workload. A main barrier for scaling up the project is that it is perceived as an extracurricular initiative.	Stakeholder collaboration is currently concentrating on the local scale, around the neighborhood. Stakeholders start integrating parts of the butterfly project in their planning. The Local Municipality has offered considerable funding for the construction of a park, which will be supported by the SLE.	Provided that quality control is maintained in data collection and processing, the project may mature into a fully-fledged citizen science initiative with considerable implications for spatial planning and the overall aim to increase flora and butterfly diversity for butterfly pollination.
Learning resources available	Resources available mainly stem from the Open University of Cyprus and include: (1) A guide with the methodology for butterfly data collection; (2) a digital tool for identifying butterfly species; (3) a database for storing butterfly data.	Stakeholders “inherit” the learning products of student projects and make them available to other students, who can use them as learning resources; this is currently facilitated through the contribution of the Natural Museum of Dali, which hosts learning products of the butterfly project	Provided that more stakeholders join, especially the Department of Forests in Cyprus and firms offering gardener services, these are expected to offer additional learning resources and increase the variety of learning products, which can be expected from the butterfly project.
Support provided to learners	The teacher works mostly on her own to support students in data collection and processing. Support by the Open University of Cyprus is crucial bot not enough to account for all learner needs and desires.	Learners are supported by two higher education institutes, the Local Municipality and the Museum of Natural History in data collection and processing and in formulating policy	Learners connect with other SLEs in the wider European “Butterfly” initiative; they exchange knowledge, experiences, and learning products; peer and teacher support from other

This project is funded by the European Union’s Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

	Business-as-usual scenario (Baseline conditions, crucial gaps and inconsistencies to address when implementing SLEs)	Small-effort scenario (Small-scale inputs potentially decisive for achieving considerable progress in the short-term)	Best-case scenario (Ideal conditions for SLEs to flourish and secure long-term sustainability)
		implications based on their data analysis.	SLEs is available and a community of practice is formed.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Funded by the European Union

This project is funded by the European Union's Horizon programme under grant agreement No 101094648. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.