Overcoming Inequalities in Informal Science Learning

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Abstract: Interest in science learning is on the raise and often related to the need for future innovators, entrepreneurs and, more generally, problem solvers. Yet, there is a concerning persistence of inequalities in educational systems, that can be traced back to learners' family, gender stereotypes or discrimination based on migratory experiences. In this paper, we present the findings of a large-scale survey (n=1,261) on informal science learning. The results show that gender and social background influence youths' attitudes toward science as well as their engagement with informal learning. The paper concludes with a design proposal for an engagement tracker enabling young learners' self-reflection and participation in designing their learning activities. Both elements, self-reflection and participation are meant to encourage science learning and diminish the gap between learners from diverse backgrounds.

Introduction

The importance attached to STEAM education (science, technology, engineering, art and math) is on the raise, given the need for future innovators, entrepreneurs and, more generally, problem solvers, who can combine the skills needed to address 21st century problems successfully. Yet, there is a concerning persistence of inequalities in educational systems, that seem to be continuously related with learners' genders, family or migratory backgrounds (Wenzel, 2011). Moreover, the influence of many socio-cultural variables from cultural, social, political, gender and family contexts on learning outcomes and success is known and documented (DeWitt et al., 2013). In that context, non-formal and informal learning scenarios are often seen as a way to mitigate these differences, since they are interest and engagement driven (Barron, 2006), possibly off-setting some of the inequalities in formal learning (Singh, 2015, p. 6). We suggest that this is particularly relevant, since learners' socio-cultural environment is shaping their taking advantage of informal learning opportunities and recognition of informal learning has been identified as a possible pathway to more inclusive "learning societies" (Stehr, 2018).

However, capturing informal learning outcomes for recognition purposes tends to start with vocational training or workplace learning (Kamarainen, Attwell, & Brown, 2002). Yet, already at an early age, informal learning is contributing to path dependencies at a later stage, e.g. whether a science career is chosen or not. Unlike in formal education settings, younger learners have no generally accepted ways of getting their informal learning outcomes recognized. Researching how informal learning can benefit youths is part of the <NAME> project, a project investigating science learning pathways for youths 9-20 years old in 18 countries across Europe and Israel/Palestine. In the long run, a better understanding of informal learning is needed to facilitate more targeted and nuanced informal learning scenarios.

In this paper, we want to show the need for and possible pathways to more equitable opportunities to acknowledge informal learning activities, given the diversity in youths' environments such as families, schools or peer groups. Although there are proxy measurements relating informal learning with a number of activities such as museum visits, do-it-yourself activities, membership in a sports club or cooking sessions, these activities can only be rough approximations of activities available to youths (DeWitt et al., 2013; Falk et al., 2016). Pragmatic ways to organize informal learning sessions, acknowledging the diversity of informal learning preferences, are still rare. Hence, our research has a twofold mission:

(a) First, we want to understand the ways informal learning does vary in accordance to youths' socio-cultural environment and related norms. This objective is addressed primarily through a large-scale survey.
(b) Second, we want to suggest a more individualistic approach towards informal learning, reflecting learners' day-to-day concerns and priorities. In order to capture these concerns and priorities we envision a co-design process working with youths towards the specifications of a learning engagement tracker.

Our underlying argument is that informal learning is more likely to be appreciated, if the opportunities for science learning are discovered by youths in their own environment. Moreover, finding scientific knowledge to be relevant for their daily actions can strengthen youths' attitude towards science and change their self-confidence as science learners (Anderson, De Cosson, & McIntosh, 2015). Hence the proposed engagement tracker will less function as a formal collector of data and be more of a self-reflection tool, promoting self-awareness as well as appreciation from others. However, the physical shape and workings of the engagement tracker will only be briefly covered in this paper, as an opportunity to create a low-cost device including sensors and internet connectivity.

In the following, we will first present related work in the areas of informal learning, tracking learning and engagement as well as systemic inequalities coming with different socio-cultural environments. After that, we present the insights of a large-scale survey (n=1,261), comparing the importance given to science by learners and their families coming from different socio-cultural backgrounds. One conclusion we are going to derive from the survey is the need to go beyond looking for evidence of informal learning and make participation of learners a central element in promoting and acknowledging informal learning. Finally, this paper concludes with some design conjectures guiding future design-based research activities to combine social science data collection methods and artefact-based data collection.

Related work: learning, tracking engagement and educational inequalities

The following three sections elaborate on the theoretical conceptualization of informal learning, introduce our focus on *engagement* as multidimensional process which links learners with their social environment and outlines possible ways of capturing engagement.

Informal learning and engagement

A common debate relates to the differences between *non-formal and informal learning*. Non-formal learning processes occur outside educational institutions and although participation is voluntary these processes occur in pre-structured educational settings similar to schools. Learning is referred to as "informal" if it does not occur in pedagogically supervised situations and is directly based on real-life situations (Stecher, 2005). If we compare the three learning settings - formal, non-formal and informal – we can see a range of benefits from 'being engaged' with the learning process. In formal settings, engagement is a requirement to cognitively processing the content taught. In a non-formal setting, engagement with science is a pre-condition to voluntarily attend a science related event and possibly follow up on the topic afterwards. When it comes to informal learning, there is actually no specific setting, since informal learning can happen everywhere, anytime. Put differently, informal learning is part of everyday live and since there is no plan or prescribed learning outcome, engagement is part of the intrinsic motivation that makes informal learners thrive.

However, engagement can happen on multiple levels. In a literature review on engagement in formal education, Fredericks et al. (2001) distinguish behavioral, emotional and cognitive engagement. They emphasize the variability of engagement in terms of time and intensity [ibid]. Adapted to an informal learning context, the three dimensions can be defined as follows: (1) *behavioral engagement,* ranging from simply tracking naturally occurring learning moments to actively searching for trackable learning moments or suggesting improvements to the tracking process itself; (2) *emotional engagement*, ranging from simply capturing affective reactions during a learning moment (boredom, interest, excitement, etc.) to valuing one's own participation and achievement during the tracking process; and (3) *cognitive engagement*, ranging from simply rehearsing knowledge to striving for a deeper understanding or contextualization of that knowledge. In real-world settings, the three engagement dimensions potentially are intertwined: curiosity (emotional engagement) can spur learners' questioning capacity (cognitive engagement), which in turn can lead to more targeted interactions with one's environment (behavioral engagement).

Hence, informal learning might provide a leverage for educational equity based on the following arguments: (1) a stronger engagement in informal learning settings has a positive impact on educational biographies as it might increase people's cultural and social competencies (Damelang & Kloß, 2013, p. 323) and (2) since participation in informal learning settings is a voluntary choice by the learner, their motivation might be higher, shaping their learning experiences (Anderson et al., 2015). This could make learning more meaningful to those who engage in it.

Tracking learning and engagement

There is an ongoing effort to bring information systems into the equation, mainly in form of creating mobile and virtual learning support (Toh, So, Seow, Chen, & Looi, 2013), but also as a means to capture informal learning outside of schools. Various sources of information to represent informal learning activities have been piloted, including peer- and self-evaluations forms, e-Portfolios, GPS tracks, photo diaries or social media.

In our context, we look at tracking as a means to make informal learning visible and focus more on the process dimension than the possible outcomes. For example, capturing informal learning can include the *geospatial conditions of informal learning*, i.e. either the place where learning occurs or the physical distance between the learner and peers or cultural facilities, such as museums, fabrication labs or otherwise stimulating environments. Writings with references to learners' locations can be found under the labels of 'place-based learning' (Smith & Sobel, 2014) or 'critical pedagogy', where situated context and social transformation are key elements in order to achieve that people can learn things that have an impact on the places they inhabit. For example, Morrison et al. (2019) emphasizes the possibilities of embodied learning for students experiencing urban design by using the city's transportation or visiting parks, thereby mashing their knowledge of design with their everyday experience as citizens and hopefully, their aspirations for future cities. In all those examples, collected data serve as a foundation for follow-up reflections either for the purpose of learning (cognitive engagement) or taking action (behavioral engagement).

Socio-cultural embedding of learning

Learning and engagement are socially embedded processes. Individuals perceive their world through the lens of prior knowledge and experiences, as well as through their interactions with others (Anderson et al., 2015). These settings, in which learning takes place, can also be addressed as "learning ecologies" (Barron, 2004), defined as a network of connected physical settings, social interactions, value systems, and histories. Consequently, each person's knowledge gain and production of meaning depends on their personal background. The influence of personal settings on learning engagement and success within the educational system has been widely discussed by Bourdieu and researchers following his theory of cultural reproduction (Nash, 1990, p. 440). Bourdieu argues that the educational system is shaped by "dominant cultural conventions of thought and action of a particular society" (Grenfell, 2004, p. 50), including socialized norms or tendencies that guide behavior and thinking, commonly referred to as habitus. The habitus which is closest to the dominant conventions of the educational system is the one of the dominant, most powerful class(es) in society – i.e. middle classes or bourgeois classes. Their norms and conventions are prescribed in curricula, educational principles, assessment criteria and grades defining transitions and pathways within the system, acting as gatekeepers for those not sharing the same habitus. The theory of cultural reproduction suggests that those children, familiar with the dominant conventions of a society, are advantaged in gaining educational credentials and will benefit more from the educational system. They are also less affected by a general decline of motivation in schools, having a rather positive response on their learning behavior from teachers and significant others (Fredricks, Blumenfeld, & Paris, 2004). In other words, success within the educational system is determined by "the degree of congruence between the cultures or subcultures into which children are socialized (…) and those that prevail in the schools" (Goldthorpe, 2007, p. 6). Summarizing, the proximity and strong interference of primary socialization (in families and through peer contacts) and secondary socialization (in schools) explains social inequalities in learning engagement at school but also outside school (Lido, Reid, & Osborne, 2019). It sheds light on social inequalities produced by the system on the one hand and the effect of the individual learners' engagement and their competences to comply with the system on the other.

Empirical evidence on the socio-cultural embedding of learning

Previous questionnaires (DeWitt et al., 2013; Falk et al., 2016) have been used to asses in how far learners' educational capital and gender influence engagement and interest in science learning. This works has been the baseline for our own data collection. However, we could not a-priori assume that existing findings would also hold for our own specific project context. Looking specifically at the socio-cultural embedding prompted us to look out for different norms and value-frames leading to possibly different result than those presented in earlier studies with a focus on US and UK learners. Hence, we tested the effects of social inequalities on (1) the learners' science interest, (2) science being important at home, as well as (3) parental encouragement to engage in science related activities. The results will be used to argue for a participatory approach to evidencing informal learning based on self-reflection and co-designing learning activities.

The survey has been conducted by 19 museums, science centers and maker spaces in 18 different countries all over Europe, including Israel/Palestine (*Authors*). Educational capital helps us to differentiate between dominant and non-dominant educational groups. More specifically *educational capital* is constructed as an index based on three inputs: (1) the highest level of education completed by one parent; (2) the current profession of the same parent, collected according to ISCO-08 major groups (International Labour Organisation, 2008); and (3) the number of physical reading materials available in the household (DeWitt et al., 2013). To include intersectional effects a composite indicator of educational capital and gender was set up, splitting low, medium and high cultural capital groups by gender, resulting in six categories (see Table 1). Table 1 also introduces the notations used henceforward, e.g. *f-low* for females from low educational households and so on. The research includes learners between 8-20 years, represented evenly across both genders. Since informal learning ecologies are age specific (Falk et al., 2016), the age of the learner can be an important intervening variable in the analysis.

Table 1: Description of independent variables

Educational Strata	Gender	Variable Abbreviation	Group Size
Low	Females	f-low	97
	Males	m-low	76
Medium	Females	f-med	287
	Males	m-med	253
High	Females	f-high	250
	Males	m-high	247
Total			**1,210**

Based on the differing group sizes and the common heterogeneous variances in the data, the following calculations were run with Kruskal-Wallis (reported as H) and Wilcoxon Rank-Sum Test (reported as W), both of which provide for rank-based non-parametric test statistics that suit our data's original distributions. The effect-size *r* was calculated based on the Wilcoxon rank-sum-Test and interpreted based on Cohen (Cohen, 1992), with r= .10 being a small effect, .30 a medium effect and .50 a large effect.

Interest in science

Based on the results of an obliquely rotated principal component analysis (PCA) with 18 items related to science attitudes, science interest was identified as a factor (Cronbach α: 0.86) based on eight items tapping questions such as: '*I enjoy learning science', 'I think I would make a good scientist', 'I find science to be really interesting', 'Science is helpful in understanding today's world'.* Accordingly, an additive index was build summarizing these eight variables, and recoding the index from 1 to 5, with 1 denoting strong disagreement, 3 indicating a neutral position, and 5 signifying strong agreement. A quarter (24.7 %) of the respondents in our sample reaches the highest category and hence exhibits a strong science interest, and in total nearly two thirds (64.4 %) of the learners exhibit a positive science interest. About another quarter (25.9 %) of respondents is undecided, while only 10 % distance themselves from a positively framed science interest (n=1261). The results (see Table 2) show, that learners science interest is significantly influenced by their educational strata (H (2) =43.832, p<.001), and while gender looked at on its own does not seem to influence science interests significantly, the combined perspective of educational capital and gender reveals the interaction of both. In our sample, boys with high educational capital score the highest on science interest with a $mean_{m\text{-}high}$ = 4.03. Thus they significantly exhibit a higher science interest than boys from low educational strata ($mean_{m\text{-}low}$ = 3.34, W = 5680, p<.001, r =.31, suggesting a medium effect) and girls from low educational strata ($mean_{f\text{-}low}$ = 3.57, W= 9016, p<.001, r =.20).

Importance of science at home

The effect of educational capital - a resource passed on by the parents to their children - leads to the question of parental science interests and support in general. *The importance of science at the learner's home* has been derived as a factor doing the same PCA introduced above and summarizes three items: '*my mother talks to me about science*', '*my father talks to me about science*' and '*my parents are interested in science*'. These three items were summed to an additive index ranging from 1, indicating strong disagreement to 5, signifying strong agreement, with 3 being undecided. (Cronbach α= .79, indicating a high reliability). One third (33.2 %) of our sample indicates that science is important in their homes, but nearly equally as much (29.7 %) are undecided, while even more (37 %), indicate that science is not important in their families (n=1253). In line with earlier findings (Archer et al., 2012) our results confirm that educational capital seems to influence the way science is a part of a family habitus (H (2) = 59.10, p <.001). Our data also confirms the strong effect of gender. In contrast to earlier findings, however, in our data girls ($mean_f$ = 3.02) indicate a significantly higher science awareness in their homes than boys ($mean_m$ = 2.87). The results indicate a large effect of gender accounting for 38 % of the variance found in parental science interactions (W = 2 12878, p <.001, with a large effect size of r = .64 (Cohen, 1992)). Yet, a closer, intersectional analysis of gender and educational capital reveals that the educational strata prevail as structuring mechanisms, with significant differences between low and high education households as well as medium and high educational capital household learners, mostly independently from gender (see Table 2). The significant effects also hold when age variance and material affluence of the household are controlled for.

Parental encouragement of science learning activities

What are the implications of science being important at the learners' homes? One might expect that this importance translates into *parental encouragement to engage in science-related activities.* The understanding of science operationalized in these activities in the survey, is based on the conception of learning ecologies and therefore, a broad definition was chosen, including 13 activities such as going to public libraries, cooking, reading, doing sports, repairing things or caring for pets (Falk et al., 2016). Parental encouragement is computed as an additive index counting the indicated encouragement of parents or guardians to engage in these science-related activities. This additive index was transformed to a 5 point scale (0 - 4) with value 0 indicating no encouragement at all, 1 indicating parents encouraging the learner to engage in a maximum of 25 % of all possible activities, a value of 2 indicates a parental encouragement up to half of all activities, 3 up to 75 % and 4 up to all activities given (n = 1261). Half of our sample (52.8 %) are only encouraged to do up to a quarter of all possible activities, a third (32.2 %) is encouraged to do up to 50 % of all possible activities, and about 1/7 (14.8 %) of the respondents feel encouraged to engage in more than half of all possible activities. Furthermore, our data indicates that parental encouragement varies with both the educational capital of the parents ($H(3) = 78.89$, $p < .001$.) and the learner's gender ($W = 220351$, $p = .008$), whereas gender differences do not hold once controlled for age.

The following table 2 shows the statistically significant differences in means between the three concept 'science interest', 'science importance at home' and 'parental encouragement', so that boys reported a higher importance of science at home compared to girls' answers. Or we can also see that differences between low and medium educational capital groups are rather small when it comes to 'science importance at home' and 'parental encouragement' compared to the difference we can see between groups with medium and high educational capital.

Table 2: Comparison of means for 'science interest', 'science at home' and 'parental encouragement' grouped by educational capital and gender

	Educational capital			**Gender**	
	L *N=179*	**M** *N=556*	**H** *N=519*	**m** *N=635*	f *N=575*
Science Interest	3.45	3.72	3.98	-	-
Science importance at home	2.60	2.75	3.24	3.02	2.87
Parental encouragement	1.50	1.43	1.62	-	-

Table 3 then provides an overview of effect sizes when comparing the means for different combinations of low, medium and high educational capital groups and gender. For example, there is a moderate effect on science interest when we compare boys from low and high educational capital groups, however the same cannot be said when comparing the means for girls from low and high educational capital groups. Furthermore, we can see a small but significant effect on 'science importance at home' when comparing groups of girls from a high educational capital background (mean = 3.27) with girls from a low (mean=2.73) or medium (mean=2.88) educational capital background.

Table 3: Comparison of means and effect sizes for 'science interest', 'science at home' and 'parental encouragement of science learning activities' grouped by sub-categories

Dependent Variable	**Independent Variables**		**Mean** [1]	**Effect size (correlation)** [2]						**n**
				f-low	*m-low*	*f-med*	*m-med*	*f-high*	*m-high*	
Science Interest	Educational Capital & Gender	*f-low*	3.57						*** 0.20	97
		m-low	3.34			*** 0.18		*** 0.27	*** **0.31**	76
		f-med	3.76					** 0.19		287
		m-med	3.70						*** 0.13	253
		f-high	3.94							250

Dependent Variable	Independent Variables		Mean [1]	Effect size (correlation) [2]						n
				f-low	*m-low*	*f-med*	*m-med*	*f-high*	*m-high*	
		m-high	4.03							247
Science importance at home	Educational Capital & Gender	*f-low*	2.73					*** 0.19	*** 0.2	96
		m-low	2.50					*** 0.25	*** 0.26	76
		f-med	2.88					*** 0.16	*** 0.16	286
		m-med	2.62					*** 0.27	*** 0.25	251
		f-high	3.27							250
		m-high	3.26							245
Parental Encouragement	Educational Capital & Gender	*f-low*	1.54							97
		m-low	1.50							76
		f-med	1.47							287
		m-med	1.40					*** 0.15		253
		f-high	1.69							250
		m-high	1.55							247

[1] Tested with Kruskal Wallis-Test (when comparing three groups) and Wilcoxon-Rank-Sum-Test (when comparing two groups). [2] $p<.05$ = **, $p<.001$=***

A possible limitation of the survey comes with the nonprobability convenience sampling, presumably resulting in a highly homogeneous set of self-selected participants exhibiting above average interest in science. In order to nevertheless obtain a diverse sample representing nondominant groups, the data collecting partners were urged to reach out to their usual range of visitors. The reached sample of 1261 responses allowed for differentiated analyses, i.e. two thirds of the participants exhibit a positive science interest including the low, medium and high educational strata of the sample. 75% of the data collection partners, used the help of schools to engage survey participants. A statistical analysis, however, did not find a significant difference between the science interest of participants engaged through formal education structures and participants engaged through other channels.

Co-designing the engagement tracker

As shown in the previous section, dependent on families' educational capital and learners' gender, sciences appeal differently to youths. Hence the idea of an engagement tracker is to create a mobile device which not only captures science learning activities but allows for co-designing learning activities in ways that are personally relevant. Relevance of learning activities could be linked to issues brought up by the learners themselves, which will vary in accordance to their own living environment. Co-design implies youths working in teams as 'experts of their experience' (Brondino et al., 2015) together with the facilitators of science learning workshop. Specific goals, based on our findings from the survey would highlight a number of co-design goals:

- strengthening learners' interest in science through creating activities that help to gain new skills and perceive themselves as youth being meaningfully engaged in 'doing science' – regardless of prior interest in science;
- empowering learners through positive feedback from others, this could be based on making informal learning visible (e.g. on maps or with badges etc);

- embracing the diversity of learners trough activities demanding different skills and competences, which might connect better to the ones of non-dominant educational groups.

Methodologically, we use design-based research (DBR), which emphasizes the importance of practice in order to understand learning as it happens in the real world (Design-Based Research Collective, 2003). It is frequently used in designing and researching innovative learning ecologies. DBR incorporates the theory-driven nature of research hypotheses and the experiential character of iterative prototyping, characteristic for design processes (Voigt & Swatman, 2006).

Current development is based on a low-cost engagement tracker, using opensource hardware, which could also be assembled and programmed by youth themselves. On a most basic level, the device captures the time of an activity and its geo-position, keeping it on the device at first, without sharing the data with some cloud service. Furthermore, the device has the possibility to use 12 touch points which can be programmed for diverse purposes. For example, we discussed the engagement tracker in the context of one workshop about bio-degradable plastics and there it was suggested that participants could map places of plastic waste and categorize them (food packaging, parts of consumer appliances, toys etc.).

Conclusion

We started with Bourdieu's theory of cultural replication, which states that one's educational capital and the prevailing habitus of one's social group shapes much of how we engage with the learning opportunities presented to us. Hence, a fairer or more equitable educational system is not simply one that offers the same opportunities to all, but one that is ready to adapt to a diversity of needs and preferences in order to make science activities enjoyable for all (i.e. equity). We then presented the results of our survey, showing how educational capital significantly impacts science interest of the learner, the importance of science in their homes and parents' encouragement of youths to engage in science related activities. We showed that these differences are intersecting with gender, leading to heterogeneous effects throughout educational strata. These identified structural inequalities pose the question of whether informal learning offers more and other learning opportunities for children and youths of non-dominant educational groups to gain meaningful, individual learning experiences.

Given the possibly positive impact of informal learning on self-perception and opportunities to use different skills learners, we then suggested a number of co-design goals. Motivation and a positive learning experiences not only depend on the learners' self-perception, but also on the (positive) response of others, explaining also why learners possessing a higher educational capital might be more engaged in learning. Hence, visibility of learning efforts is also a precondition for recognition, improving learners' engagement. By making the individual learning experiences meaningful and visible for others, we argued that learners prove the value of their learning engagement. A visualization can, for example, be part of learning portfolios and other tools providing evidence on personal engagement.

Lastly, we are aware that here is a massive proliferation of tracking devices and tracking data in a world where Big Data play an increasingly important role, even though their impact is seldom recognized by those who generate the data (Boyd & Crawford, 2012). This development will not stop at the doors of educational institutions. Although data have always played an important role in education (enrollment, dropouts, success rates, grades etc), the possibility of tracking behavioral data at a very fine-grained level opens up a new dimension of learner modelling and predicting learner development. Whether these new possibilities will be used to support learning, closing the gap between those who thrive in the current system and those who struggle to adapt, is a question that needs close monitoring.

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