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Young Peoples' Online Science Practices as a Gateway to Higher Education STEM

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Abstract
The purpose of this manuscript is to explore how students perceive that online practices have enabled their participation in university physics programmes. In order to conceptualise how students bridge their science participation across physical and online spaces, we make use of the learning ecology perspective. This perspective is complemented with the notion of science capital, analysing how students have been able to strengthen different aspects of science capital through online participation. Data has been generated through semi-structured interviews guided by a timeline, constructed in collaboration between the interviewer and the interviewee. Twenty-one students enrolled in higher education physics have been interviewed, with a focus on their trajectories into higher education physics. The findings focus on four students who in various ways all have struggled to access science learning resources and found ways to utilise online spaces as a complement to their physical learning ecologies. In the manuscript, we show how online practices have contributed to the students' learning ecologies, e.g. in terms of building networks and functioning as learning support, and how resources acquired through online science practices have both use and exchange value in the wider science community. Online science participation is thus both curiosity driven and founded in instrumental reasons (using online tutoring to pass school science). Furthermore, we argue that online spaces have the potential to offer opportunities for participation and network building for students who do not have access to science activities and science people in their everyday surroundings.

Keywords Informal learning · Higher education physics · Learning ecologies · Science capital

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Introduction

> I don't think I would have done science, had it not been for the internet. Really, it's had such a massive effect. Cause I cannot get help at home. (Abid)

Today, the internet form an important part of people's lives, making it possible to access a wealth of different communities and resources from virtually anywhere. This of course includes online resources related to science, and the interview excerpt above illustrates the potential importance of such resources, in particular for someone who has had limited access to other science resources. In this manuscript, we explore the role of online science practices[1] in students' trajectories leading up to their decision to study higher education physics, with a particular focus on minoritised students.

Already in 2009, Greenhow and Robelia argued that contexts for teaching and learning were becoming more complex, as young people were learning across a range of different physical and cyber spaces. They elaborate: 'students practice formal, informal, and non-formal learning across a wide range of contexts and exercise considerable authority over how they learn, when they learn, and with whom' (p. 122). Today, online participation serves a multitude of purposes for young people that are potentially related to their science engagement. Not only is the internet the most widely used source for science information (Brossard & Scheufele, 2013; Hargittai et al., 2018), students also use social media in their educational decision making (Galan et al., 2015), and for engaging in identity work and self-expression (Barron, 2006; Greenhow & Robelia, 2009).

In particular, research has explored the role of social media to support learning and interactive engagement in both formal and informal contexts (Greenhow & Lewin, 2016; Lundgren et al., 2020; Russo et al., 2009). Greenhow & Lewin, (2016) argue that '[s]ome young people, although in the minority, are engaging fully, initiating self-directed learning activities utilizing the full potential of participatory and collaborative technologies. Harnessing the learning attributes of social media could enrich young people's experiences of learning in institutional contexts' (p. 24–25). In addition, Greenhow & Robelia, (2009) found that the students in their study used a social network site both to explore various dimensions of their identity and to practice twenty-first century skills.

Today, almost all young people in Sweden have access to internet at home (Statistikdatabasen, 2022) and are therefore able to access a wealth of online science resources. However, there are studies showing gender differences in engagement with science on Youtube, both concerning presenters (Amarasekara & Grant, 2019) and consumers (Landrum, 2021). In a study of over 500 viewers' use of Youtube, Landrum, (2021) found that men were more inclined to watch science and technology videos than women (for science, there was a small gender gap, and for technology a larger gender gap). Landrum, (2021) also found that men to a higher degree than women cited entertainment as the reason they watched science videos, whereas women to a higher degree cited watching science videos for informational purposes. In addition, it can be noted that research shows that participation in informal science education activities in general is the highest among young people from privileged groups (DeWitt & Archer, 2017; Godec et al., 2021). The abundance

[1] With online science practices, we mean any activities the students are engaged in that they conceptualise as being related to science and that take place in an online environment (that is, on a computer or other device connected to other computers). Thus, while 'online' often is taken as referring to the internet, it can also include e.g. local area networks.

of online science resources coupled with the potential significance of such resources for young peoples' science engagement and the unequal participation in some online practices motivates a deepened exploration of the role of online science practices for students' learning and identity formation.

Purpose and Research Questions

The purpose of the manuscript is to explore how minoritised students perceive that online practices have enabled their participation in higher education physics. The research question is:

> How do the students give meaning to their online practices in relation to their science education trajectories?

Conceptual Framing: Science Capital and Learning Ecologies

The concept of science capital, developed by Louise Archer and colleagues, draws on Pierre Bourdieu's sociological theory. It is a way to collate science-related forms of cultural and social capital, as related to a person's science identity and their prospective participation in science. The concept has been developed by large-scale quantitative and qualitative studies of young people in the UK, and has been shown to be more closely related to science aspirations than cultural capital (Archer et al., 2015; DeWitt et al., 2016). Archer and colleagues have formulated eight different dimensions of science capital that are the most closely related to science participation beyond compulsory school and students' sense that science is 'for them'. Essentially, the dimensions are related to scientific literacy, attitudes to science, knowing people in science-related roles (contacts) and participating in science activities. Measuring individuals' science capital in a small-scale qualitative study such as this is of limited significance. Rather, we focus on how our participants have been able to strengthen different aspects of science capital through online participation. In particular, we are interested in how online resources have contributed to accumulating capital, thereby reinforcing students' science identities. Following Black & Hernandez-Martinez, (2016) and Author et al. (YEAR), we distinguish between the use value and the exchange value of different aspects of science capital, both of which can support participation in post-secondary science. *Use value* of capital concerns the possible application of, for example, knowledge or skills in a new setting, thus supporting participation and engagement in science. *Exchange value* concerns the possibility to accumulate more science capital.

To conceptualise the role of online science practices for students' acquisition of science capital, and how students bridge their science learning across physical and online spaces, we utilise the learning ecology perspective (Barron, 2006). Barron, (2006) defines a learning ecology as a 'set of contexts found in physical or virtual spaces that provide opportunities for learning' (p. 195). Following the argument in Greenhow & Robelia, (2009), drawing on Barron, (2006), the learning ecology framework highlights that young people are involved simultaneously in many different settings and that boundaries between settings are permeable, meaning that they create learning contexts for themselves both within and across settings. As such, drawing strict boundaries between informal and formal learning in the case of online spaces, such as social media, is argued to not be beneficial (Greenhow & Robelia, 2009). Likewise, the learning ecology framework rests on an assumption that the

Table 1 Overview of interviewees figuring in the manuscript

Interviewee	Parents' occupations	Parents' birthplace	Upper secondary school
Abid	Child minder Restaurant owner	Non-European countries	Science
Tobias	Truck driver Early retirement due to illness	Sweden	Vocational
Konrad	Shop assistant Carpenter	Sweden	Vocational
Sigrid	Engineer Engineer	Sweden/European country	Science

boundaries of formal education can be porous (Barron, 2004, 2006). Hence, we consider online science practices as integral to students' learning ecologies. In doing so, we analytically zoom in on the students' strengthening of their science capital through online science participation.

Method

Data Collection

The data for this manuscript comes from a project focused on the educational trajectories of students from groups historically under-represented in physics. In total, twenty-one students enrolled either in a bachelor of physics or engineering physics programme in Sweden were interviewed. In the recruitment to the study, through a mix of information in lectures and advertisements in physics departments, prospective participants were informed that the study concerned under-represented students, but that we also were interested in interviewing students from all backgrounds.

The interviews were semi-structured and guided by a timeline, constructed in collaboration between the interviewer and the interviewee (Adriansen, 2012). The interviews were mainly structured around the students' trajectories to higher education physics, with a particular focus on events and people the students ascribe importance to for their decision to study physics. To a lesser extent, interviews also explored the interviewee's experiences of higher education physics (Table 1). Events and people were added to the timeline as the interview progressed. One of the themes in the interview were different aspects of science capital (DeWitt et al., 2016). Here, the students were prompted both with more traditional means of engaging with science in informal contexts (e.g. popular science books and magazines, science TV shows and museum visits) as well as online practices related to science. However, it is important to note that the aim was not to perform a comprehensive mapping of the students' access to and use of online resources; rather, we focused on the overall resources that the students brought up as relevant to them during the interview.

The interviews lasted between 60 and 120 min and have been transcribed by professional transcribers. All interviews were performed in Swedish, and English excerpts used in the manuscript have been translated after the analysis. In the manuscript, the stories of four students from minoritised background are analysed. All four in various ways narrate themselves as outsiders in relation to formal physics education, and have been chosen as focal students for this manuscript because they ascribe vital importance to online science practices. The project follows the Swedish Research Council's ethical guidelines and all interviewees have given informed consent in writing. The project has received ethical clearance by the Swedish Ethical Review Authority. All names are pseudonyms, and chosen to reflect the age and background of the students. Descriptions of universities and schools are deliberately vague in order to preserve anonymity.

Analysis

In the first round of analysis, the transcripts were read with a focus on which kinds of online resources the students' highlighted in relation to their science education trajectory (that is, resources they explicitly talk about as having enabled their participation in science education). These were listed (e.g. watching Youtube videos, gaming, watching online lectures) and then thematised into four broader themes (online tutoring and the internet as learning support; online science media use; gaming and programming; social media). In the next analysis stage, we looked for the functions of students' online science participation (i.e. what purpose a particular kind of participation served). In this analysis stage, we used the different aspects of science capital (Archer et al., 2015) as a framework for characterising the functions of the online science participation, also attending to the use and/or exchange value of particular resources. Thereafter, one student narrative was chosen to illustrate each theme (all themes were present in several student narratives). By reporting the findings in terms of four narrative cases, we aim to provide a more holistic perspective on how the students' use of online resources makes up part of their learning ecologies and thereby also enhance the transferability of the findings. In the final analysis stage, we zoomed in on how online science participation was part of the four students' learning ecologies and zoomed out to consider how these four students' learning ecologies differed from the data set at large. The analysis was carried out by the first author, but checked and discussed with all authors, who were familiar with all the interview data.

Findings

The findings hone in on four out of the twenty-one interviewed students, in order to illustrate different ways in which students utilise online science practices to acquire science capital. The focal students are three man students from non-academic backgrounds (Abid, Tobias and Konrad), who in one case is a first-generation immigrant (Abid), and one woman student from an academic background (Sigrid). In the following, we will present how science capital acquired through four different online practices (tutoring, science media use, gaming and programming and social media) has use and exchange value in the post-secondary physics community.

Online Tutoring and the Internet as Learning Support

For most young people, online practices form an integral part of their everyday lives and accordingly several of the students mention in passing that they have supported their science studies with online resources, such as information searches. As such, it can be expected that online science resources form part of many students' learning ecologies, but without necessarily being clearly discerned as a separated practice. However, for Abid, a first-generation immigrant from a non-academic background, the importance of online resources for his science participation is much more pronounced. No one in Abid's immediate family has gone to university. Abid has not had the possibility to get help with school assignments at home. Yet, schooling and science were still valued in his home, centred around the family's admiration and respect for a relative in an older generation who had trained as an engineer in their native country. During lower secondary school, Abid started to use Google as a way to find help for school assignments: 'Always when I had a problem I googled. If there were assignments I couldn't solve, it was the internet'. Abid early on had access to his own computer at home, provided by his father, who, despite working in another business, is described as very interested in computers and recognised the potential of computers for school work.

Later, in upper secondary school, Abid found it difficult to ask the teacher for help, and he also did not want to ask his classmates, since he perceived the atmosphere as competitive. Once again, the internet provided learning support, but not only in terms of accessing information, but also through online tutoring. As such, the very participation in school science for Abid is possibilised by online resources. He explains:

> Abid: I don't think I would have done science, had it not been for the internet. Really, it's had such a massive effect. Cause I cannot get help at home. I couldn't really talk to my teacher in upper secondary school. So the only outlet I had was the internet, that was a wonderful resource. I think about, it's sick how much… Even now when I cannot ask people… Like, I don't blame them, I get it, it's… The circumstances are like they are and I've been given the circumstances I've been given. But I'm very grateful that I've had access to the internet.

In the interview, Abid describes his uses of online resources in upper secondary school with the use of two different tutoring websites, one where university students act as coaches and one where different users of the website can post replies to each other's questions. Both websites are free of charge and participation is anonymous. For Abid, online tutoring has made participation in school science possible, and the way he used online tutoring and the internet to support his science learning suggests both use and exchange value. The use value concerns how this practice is one that he has been able to fruitfully apply across lower and upper secondary school as well as in his current university education. The exchange value is mainly through grades: with the help of sites for online tutoring, Abid was able to pass science in upper secondary school, and the passing grades gave him access to higher education.

Online Science Media Use

The most common form of online media use described by the interviewed students is the use of YouTube to access science videos. Several students talk about following science YouTube channels (e.g. National Geographic) and particular science Youtubers (e.g. Veritasium). The students also use YouTube in particular and the internet in general to access talks by well-known scientists. This gives access to a multitude of science resources, both in the form of popularised content and content aimed at professional scientists. The students described using such content as a source of inspiration and to access more in-depth information about physics areas that interest them. This is particularly important for students who do not have access to such resources at home or through their school and who in this way can strengthen their science capital in terms of scientific literacy as well as attitudes towards science.

Tobias, who comes from a non-academic background, describes the internet as one of his main sources of inspiration and information regarding science. When asked about his route to higher education physics, he immediately pinpoints two main sources of inspiration: his older brother (who now is an engineer) and the internet. Marking important people and occurrences on his timeline during the interview, he also writes ‘internet’. None of Tobias’s parents have gone to university, there are no other university-educated people in his extended family, and there were few books in his childhood home, but he got access to more advanced school books and some popular scientific books through his brother. Still, science capital was sparse in Tobias’s family. Furthermore, Tobias narrates that he did not engage with school science at all. He describes himself in lower secondary school as being very interested in physics—but uninterested in school physics and not proficient in mathematics. In upper secondary school, Tobias made the choice to pursue a vocational programme, having decided to limit physics to a hobby. Yet, throughout upper secondary school and his subsequent university education in arts, he sustained a multi-faceted physics learning ecology comprised of conversations with his brother (who was now in engineering education) and the brother’s friends and physics teachers in the upper secondary school he attended, as well as using the internet as a source of physics inspiration and information. For example, he talked about spending long hours, often at night, watching online physics lectures and other physics videos. For Tobias, this also gave a sense of stability and tranquility in an otherwise rather chaotic everyday life. Physics was not a part of the curriculum in the vocational upper secondary programme Tobias attended, but he regularly visited the physics teachers who taught at the science programme in another part of the school and spent time in their staff room.

So, despite a very limited engagement with school science, limited family science capital, and no friends interested in science (‘the friends I hung out with on a daily basis were not interested in physics at all’), Tobias was able to sustain an engagement in physics that was in part driven by his online physics participation. Overall, the online physics participation and interactions with the physics teachers and conversations with Tobias’s brother and his friends all build on one another. As such, while Tobias’s engagement with physics online was largely a non-interactive one, in that he watched videos and lecturers rather than participated in, for example, online social media communities, it still contributed to his social contacts with other people in physics. Consequently, Tobias’s online science engagement enabled relationships and network building with other people interested in science (like the teachers and his brother’s friend). In this way, the online science engagement has both use and exchange value. The use value concerns the applicability of science content accessed online in conversations with other people interested in science. Its exchange value concerns being able to exchange knowledge and skills acquired in the online science engagement for additional science social capital, in that it provides a basis for interactions with other people interested in science and thereby facilitates relationships and networks. However, such relationships and networks can also be enabled by practices that do not have direct use value, and it is one such practice we turn to next.

Gaming and Programming

In the case of Tobias, online resources contributed to his building of social capital in science, in that the science knowledge acquired through watching online science lectures allowed him to build relations both with his brother's engineering student friends and with the science teachers at his upper secondary school. Konrad, who comes from a non-academic background, talked about how he developed an interest in computer gaming, together with a couple of friends, during lower secondary school. These friends went on to study the science programme in upper secondary school, whereas Konrad chose a vocational programme. However, through his interest in gaming and his gaming friends, he connected with students in the science programme, where an interest in gaming and computing was an integral part of the peer culture:

> Konrad: [Gaming] was the main way I hung out with people. And then during upper secondary school I met other people. And I met students from the science programme because of my other two friends, then, because students in the science programme are very interested in gaming, very interested in computers. You cannot talk about building computers in the [programme I attended], because they don't find it interesting […] So then I hung out more and more with students in the science programme, who also were into gaming and computers and simulators and such. And above all it was always very interesting to hear what they had done when they had programmed something.

Hence, in the vocational programme, Konrad attended his interest in gaming and programming was unusual, but through his friendships with students in the science programme, he was able to access a community of young people interested in science and technology. This peer group also contributed to Konrad's knowledge about academic professions and family cultures in which talking about science was part of everyday life. Involvement in gaming in this way had exchange value, in that it could be exchanged for science social capital. Programming competence, in addition, can also have a more practical use value in university science education. This is however not explicitly highlighted by Konrad, who focused on the social capital his interest in gaming and computers have afforded him.

Social Media

Unlike Abid, Tobias and Konrad, Sigrid comes from an academic background and both her parents work as engineers. Prior to university, she has also participated in numerous science summer schools and internships. Still, she expresses a discomfort when it comes to participating in discussions and answering questions in the higher education physics classroom, and struggles to find a place in this learning context. To complement her already very multi-faceted learning ecology, she has initiated a science association, specifically aimed at women and non-binary people, that combines online community building and events with some physical events. For Sigrid, this community has provided very important support for her:

> Sigrid: I've put an arrow for it on the timeline, because I notice that the more I… or I'm still very involved in that organization and I notice that I get more self-confidence and I became… like, much more secure in myself and my interests, I think it's fun. I feel so much better in that community.[…] [in this organization] I've never felt that I don't fit in, or that I don't have something important to say, or that I cannot participate in a discussion in the [organization] or in that community overall. It feels as if my point of view is very valid, and that I have enough knowledge to talk about this.

In Sigrid's case, the online participation in a science community for women and gender diverse people has served an important purpose in terms of providing support and building self-confidence. In particular, she stresses the positive atmosphere in the community and how she does not feel inhibited to participate in discussions in this context in the same way as she does in her physics studies. As such, Sigrid builds her science capital in the online community context, both in terms of scientific literacy and social capital. This science capital has both use and exchange value in the university physics community. The skills Sigrid gains in the online science community, such as participating in science discussions, also have use value in the university physics community.

Synthesis: Online Practices as Part of Minoritised Students' Learning Ecologies

When mapping students' use of different online resources, it is noticeable that such resources are absent from most of the narratives of students with an otherwise strong academic capital and/or science capital (acquired either through family or schooling). In the narratives of students with strong academic and/or science capital, it is the resources related to family or school science capital that is at the centre of the story: parents' and siblings' education and professions, schools specialised in science and out-of-school science activities.

For Tobias and Konrad, online science practices were for a long time their only engagement with science. Abid attributes crucial importance to online tutoring and to the internet as a source of information about science for his possibility to study higher education physics. Sigrid, who feels like an outsider in her physics education, has found a safe space for science participation in an online science community. These four students are examples of how online science practice has contributed to enable participation in higher education physics for minoritised students, offering access to science content as well as science communities, thereby strengthening the students' science capital.

In all four cases, the boundaries between formal and informal science education practices are permeable, and the students form learning ecologies across online and physical learning spaces. The relationship between different parts of the students' learning ecologies is different however. Konrad was able to exchange his interest in gaming and computers for science social capital, which contributed to a widening of his science learning ecology. However, the use value of the skills gained in the gaming community is limited in his wider science learning ecology. For Abid, the online science practices blend seamlessly with school science, and similarly, Sigrid's participation in a science community for women and non-binary people has both online and offline components. Hence, in both these cases, the students' learning ecologies entangle online and offline components. Yet, for Abid, Sigrid and Tobias, online science practices have enabled a type of participation that they have not perceived as possible in formal science education contexts. For Tobias in particular, science conversations made possible by these online practices formed a learning ecology in parallel with formal schooling.

Discussion

Online spaces can offer opportunities for participation and network building for students who do not have access to science activities and science people in their everyday surroundings. In the age group 16–24 years virtually, everyone has access to the internet

(Statistikdatabasen, 2022). As such, online science activities have the potential to contribute to widening participation in higher education STEM. Still, it is important to be mindful that students from privileged backgrounds participate in informal science education to a higher degree (DeWitt & Archer, 2017; Godec et al., 2021) and that gender gaps favouring male students have been found in online science participation (Amarasekara & Grant, 2019; Landrum, 2021). While it is not possible to make statistical generalisations for our small-scale, qualitative study, it nevertheless highlights how important online science resources have been for students from non-academic backgrounds, who otherwise have lacked opportunities to acquire science capital.

The online science participation of the interviewed students is both grounded in instrumental reasons (using online tutoring to pass school science) and curiosity driven. In the students' talk about their science participation, no sharp boundaries are drawn between formal, non-formal and informal learning contexts. It is noticeable how, for example, online tutoring blends with school science and how the activities in the organisation Sigrid participated in (both the online and the physical ones) cannot be easily categorised as formal or informal. The organisation is not explicitly connected to formal education, and still strongly connects to higher education science in its mission to increase the recruitment of women to such educations. The interviewed students can be understood as creating learning contexts for themselves both within and across settings, whether these are formal, informal or non-formal, or online or physical. Consequently, in order to understand how these students utilise a variety of resources in their physics learning and participation, it becomes important to reconceptualise boundaries of formal and informal learning (Greenhow & Lewin, 2016) as well as boundaries between online and physical learning spaces. Considering how the online science practices are not geographically bound these practices can also offer resources that sustain life-long learning in science.

In the interviewed students' narratives, we see how a variety of online science practices (tutoring, media use, gaming and programming and social media) are discussed by the students in relation to their science education identities. The science capital acquired through online science engagement in some cases has exchange value (e.g. gaming) and in other cases both exchange and use value (e.g. online community building). A nuanced consideration of how different online practices contribute to science capital can help make visible how minoritised students in particular may be able to acquire science capital beyond family, school and institutionalised informal science education contexts. As such, the study has highlighted the importance of online practices (online tutoring and gaming) that are likely to not be institutionally sanctioned in education contexts yet have played an important role for students depleted of other possible means of acquiring science capital. Other forms of participation are strongly institutionally sanctioned. In particular, Sigrid's founding of and participation in an organisation for women and non-binary people in STEM aligns very well with policy discourses concerning the recruitment of more women into mathematics intense STEM disciplines (Cumings Mansfield et al., 2014). In this way, Sigrid's online engagement not only provides networks and support; being involved in the kind of widened participation work the organisation is concerned with can also be considered symbolic capital in the STEM community.

For all four students, the involvement in online science practices has had importance for their science identity formation. For both Abid and Sigrid, online participation has provided safe spaces, where they have been able to participate on their own terms, without the perceived focus on performance of formal education contexts. For Konrad, the context of gaming and programming provided a social context where he could meet other people interested in science and technology, and allowed him to recognise himself as similar to people who were involved in formal science education or academically trained. For Tobias, the knowledge and skills acquired through online participation also supported the teachers' recognition of him as a 'science person' although he at the time was not involved in formal science education. Hence, online science practices may afford recognition and participation for students for whom the formal education contexts are perceived as uncomfortable (Abid and Sigrid) or inaccessible (Tobias and Konrad).

To summarise, the availability of online science resources makes it important to consider those as part of students' learning ecologies, both from the perspective of researchers and practitioners. First, the potential of making science available to students with little science capital through widely accessible online practices is promising from the perspective of widened participation. However, in doing so, it is important to be conscious of the potential in-/exclusions created by online practices (such as, which student groups that are more likely to be involved in programming and gaming). Second, given the potential centrality of online resources for students' science participation, we argue that it is important to take a nuanced approach to how online science practices contribute to students' science capital, without creating sharp boundaries between such practices and physical practices. In order to do so, it would be valuable to capture students' learning ecologies to learn more about the informal practices that support participation in physics—and possibly increase the valuing of some of those informal practices.

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Declarations

Conflict of Interest The authors declare no competing interests.

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