"IT'S NOT LIKE IT'S POPULAR SCIENCE WE ARE DOING"

- POPULAR SCIENCE, MOTIVATION, CALCULATIONS, AND CONCEPTUAL UNDERSTANDING AMONG PHYSICS AND ENGINEERING STUDENTS (RESEARCH)

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ABSTRACT

This paper discusses the role popular science and science dissemination texts can have in learning physics in higher education for physics students and technical physics engineering students. In a mixed-methods study, students' attitudes, experienced motivation, and learning is mapped through a quantitative survey (N=155) and two qualitative surveys with in-depth interviews, one with six master level students and one with four 1st year students. The interview data shed light on two aspects of popular science's role in learning physics. Students report that reading popular science is highly motivating, but they do not have the perception of having learned physics from it. This converges with a division between calculations and conceptual understanding among the students. The paper then questions whether this gap could be closed or made smaller with greater emphasis on conceptual understanding in physics classes.

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1 INTRODUCTION

In this study, we will examine the role of popular physics in motivation and learning in university-level physics education. We will try to answer the research question:

What contribution can popular science have as a learning tool, and how can it be employed as one in university-level physics?

Literature and experiences with popular science and physics education describe several tensions and dualities when it comes to the view of popular science from an academic perspective. We will particularly look at the literature regarding popular physics, but also use some considerations from the wider field of popular science.

1.1 The societal function of popular science

The first question we should apply is to define popular science. There is no common definition of what popular science is. A simple demarcation could be that it should be both “popular” - directed at a mass audience without strict demands on pre-knowledge, and “science” - it should be based on scientific knowledge, not fiction (or science fiction). As such it will have a large overlap with science dissemination texts, with one main difference being the latter having the stated objective of scientific dissemination.

However, one seminal text on the topic proclaims that ”If we are then to think of popular science as part of a conceptual ecosystem, we might then also have to conclude that there is no such thing as popular science.” [1] On the other hand, the author continues to argue that ”for popular science: it is not a thing, nor a category but a historical phenomenon that happens in human relationships.” In other words, do not ask what popular science *is*, but what popular science *does*.

We will firstly look at discussions on the role of popular science in society. This is not our primary objective - that is the effect on students - however, as little as physicists might like it, we too exist in society [2] and for our students, society is the primordial ooze they crawl out of on their way into the domain of physics.

In this area, the literature on popular physics mainly revolves around the role of popular science in domain conflicts, with common references to C.P. Snow’s “Two cultures” [3] and the United States’ “Science Wars” of the 1990s [4].

As an example, Felicity Mellor describes how ”The intertextuality of popular science books causes images of science which are supportive of scientists’ interests to continue to circulate in public discourse despite the alternative images thrown up by public scientific controversies reported in the news.” [5] Popular physics books are here thus seen as a tool for scientists to dominate not only science but also the public discourse on science in a process similar to a Gramscian struggle for hegemony [6].

In science, there has been a general concern about “public understanding of science“ and hence science has the responsibility to inform. “Scientists must learn to communicate to the public, be willing to do so, and indeed consider it their duty to do so" [7]. This will also to a large part be through science dissemination texts which will fall within popular science.

1.2 The effect of popular science on students

Drawing on a wide range of literature Christidou proclaims that «Popular science, communicated by the mass media, the internet, comics, films etc., pervades information sources widely used by young students -and the public in general- and is therefore considered as greatly influencing students' conceptions, interests, and attitudes towards science." [8].

We here, however, also find a duality, because even though it is important in forming and shaping students' views of science, "These information sources often promote intense, outdated, controversial, stereotypic and gender-biased images of science and its people." [8]

This duality is about motivation and the view of science, but also of its practitioners, which popular science promotes. Similar dualities can also be found in the views on the effects popular science can have on learning physics. There does not seem to be a lot of literature on this topic, but there are a few more experience-based accounts that can give us an impression of the views on popular science from scholars in the relevant fields.

Lam [9] holds that «The use of popular science (PS) books is a long-neglected tool in teaching. [...] The idea is to help the students to broaden their scientific knowledge base as demanded by the real world out there, to foster a lifelong habit of buying and reading PS books, and become a science-informed citizen." In such a perspective popular science can be a contribution to Bildung, in the sense of the German/North European tradition of education of popular enlightenment and connecting one's education to one's role as a citizen [10].

However, there are some worries about whether popular science might be more popular than it is scientific. Henry [11], e.g. observes that "However what sometimes happens is I see candidates who can regurgitate a lot of facts they have read in popular science books or New Scientist, but are then unable to relate this to the physics they have learned at school. They tell me about the Large Hadron Collider and the Higgs Boson, but get stuck when asked to draw the trajectory of a particle in an electric or magnetic field." In this context, research on physics cultures sometimes one-sided focus on calculations should be mentioned as a possible partial explanation of the latter [12].

Leane also questions the scientific rigor of popular physics books. She e.g. points out that her "analysis of the use of metaphor in Zukav's The Dancing Wu Li Masters identifies the slippage of meaning that renders this text more of a hindrance than a help to cross-disciplinary communication." [4]. There is thus a fear of simplifications that can hinder learning instead of strengthening it.

There thus seems to be a gap between the physics they read in popular science books and “real physics”, i.e. the physics they learn in school or college, and the students cannot connect the two.

1.3 The effect of popular science on students

In reviewing the relationship between popular science and motivation we will employ self-determination theory (SDT) as described by Deci and Ryan [13]. SDT’s describes three basic psychological needs, essential for motivation; autonomy, competence, and relatedness.

The first one, autonomy - the experience of being self-regulated in one’s actions and experiences. Life as a student will always have the volitional aspects of being a student, feeling congruent and integrated, and not controlled by others, but at the same time, controlled by deadlines, a defined curriculum, and the final exam.

A second element is belonging - the experience of belonging and feeling socially connected. In this sense, it could be relevant to connect this to the discussions of popular science as a tool in domain struggles [4]. A university department will have a strong role in managing and controlling the professional domain of physics. In the sense that popular physics, perhaps written by a seasoned physicist, can give a student the feeling of access to this domain, it can be highly motivating. However, the skepticism towards aspects of popular science found within the same professional domain [4, 11], will also affect students’ attitudes in the process of entering the domain of physics.

The third element, competence, is more contentious. How can students experience mastery and effectance from popular science if they struggle to connect it to their “school physics” [11]? One possibility is the overview popular science can give you [9]. If they do manage to connect it to the physics they learn in lecture halls, it can help the students to position it within a wider framework of knowledge.

When students enter the field of science, they are motivated to start studying and have a goal to finish, but, arrive with various knowledge about the path into the domain. Goals are representations of future scenarios that remain in memory, stored as knowledge structures. A goal can be defined as a “cognitive representation of a desired endpoint that impacts evaluations, emotions, and behaviors.” [14]. Parts of this domain knowledge may be created by popular science.

2 METHODOLOGY

2.1 Section 1

The quantitative analysis is based on the Interactive Engagement and Motivation in Physics Learning (IMPEL) survey [15], which again is based on the Eccles-model within motivational theory [16]. The respondents are 157 first-year students from a physics class, composed of students where roughly one third are part of a bachelor physics program and two-thirds belong to an applied physics and mathematics 5-year engineering program. The students are asked about their motivations and perceived learning from different activities on a 5-point Likert scale.

We do a simple quantitative comparison of these IMPEL data on questions of perceived learning and motivation.

The 6 Master level physics students have gone through semi-structured individual interviews of approximately an hour length each. The data have been transcribed and are interpreted through a Phenomenological analysis looking for larger recurring meaning-units, using a process of meaning condensation from Giorgi [17-19].

We have also included elements from interviews of 4 first-year physics students. These interviews were mainly focusing on how students viewed their learning process facing the first course of mechanics but are included as there were elements from the interviews relevant to this current topic as well. The interviews were conducted by Martine Strand, a Master's student of Thorseth**.** These data were analyzed using thematic analysis as developed by Braun and Clarke [20].

We do not claim these qualitative data sets give reason to generalize to all physics students, not least as they are all from one Norwegian university, but also because it is a qualitative survey of a few students. We however believe these results may shed light on the quantitative results, and direct further research into whether and how popular science can be employed to increase student learning.

3 RESULTS

The quantitative results from this study show a huge gap between the perceived learning and motivation from popular science in physics. The qualitative data give us some suggestions for the mechanisms behind this gap and how it can be reduced.

3.1 Popular physics as motivation

The scores from the IMPEL-survey are presented in Table 1. If we first consider the responses on motivation, we see that all the popular science activities enter the top half, and 2 out of the top three most motivating activities are related to popular science. Only direct human interaction with peers tops popular science. When asked about perceived learning the popular science activities however drop dramatically. Watching popular science videos now get a medium score, while reading and lectures are placed in the bottom half. This difference between perceived learning and motivation can not be seen in any other activities. To clarify this we can look at the difference between the scores and see that apart from programming (which was not yet integrated well into physics for this student group) popular science are the only activities that motivate more than supply experienced learning, but also that the difference on a 5 point scale, between - 0,58 and - 0,82, is of a different magnitude than any other activities.

In examining the responses from the 6 master students we can confirm the motivating role of popular science. In describing their path to physics five of the six mention either popular science or fascination with the “big questions” about the universe as a key factor in their path to physics, often in connection. The same students, however, also reproduce the duality found in literature when it comes to perceived learning.

Table 1. Student responses to whether they experience learning and motivation from a range of learning activities on a 5-point Likert scale. The difference in mean score between learning and motivation is presented in the final column. The number of respondents, N, on the different questions ranged from 154-157 respondents.

	I learn physics well by…		I am motivated by…		Learn well minus motivated
	Mean	Std.dev	Mean	Std.dev	Mean
listening to the teacher talking in lectures	3,26	1,139	3,06	1,172	0,2
watching the teacher doing a demonstration	3,89	0,898	3,75	1,004	0,14
doing experiments	3,31	1,122	3,1	1,172	0,21
discussing subject matter with fellow students	4,5	0,799	4,32	0,843	0,18
solving problems with fellow students	4,46	0,83	4,23	0,944	0,23
solving problems alone	4,45	0,73	4,02	0,886	0,43
receiving help from a learning assistant	4,16	0,94	3,84	0,951	0,32
reading in textbooks	3,63	0,985	3,28	1,144	0,35
programming	2,55	1,024	2,81	1,127	-0,26
finding information I need by searching	3,61	0,918	3,4	1,033	0,21
watching podcast of lectures	3,03	0,872	3	0,95	0,03
popular science talks about physics	3,24	1,012	4,06	0,969	**-0,82**
reading popular science about physics	3,22	0,972	3,95	1,002	**-0,73**
watching popular science videos about physics	3,64	1,053	4,22	0,906	**-0,58**

Student 2 e.g., shows how she has made an autonomous choice of going to popular science to keep her motivation for physics up: "*I have in a way, parallel with my studies, to keep the spark, had to read popular science and sort of getting some* *input on that side parallel to my studies.*" We can see that this activity supplies motivation she needs for her studies. At the same time, it is considered as something separate from them. She also separates the two with the following description of her studies: "It's not like it's popular science we are doing".

Similarly, we can see from Student 3. "*I read about it, about physics on quite a popular science level, but… it was something I found quite interesting*", while at the same time describing his knowledge in one field: "*When we start talking about quantum field, because I haven't had that, it still becomes for me, like, popular science, because I don't know anything about that.*" We see here that popular science becomes a description om "not knowing anything about" something.

Student 6 brings in the same skeptical view: "*I always felt that when you read popular science, you become a little insecure - do you understand this? To understand physics, you sort of have to work intensively with it over a long period of time and the understanding comes gradually. If you read a popular science book, it's interesting, but the you think: 'Do I really understand this now?'*"

3.2 Conceptual understanding vs. calculations

Understanding how the world works is a central motivational point for physics students, most of the interviewed Master's students regard conceptual understanding as important for choosing physics. All students stress the importance of conceptual understanding in physics. Two students without being asked explicitly, point to the use of math to describe physical reality rather than just math itself, as the reason they chose physics over math.

The reality in physics education is however that many of these students believe there is too little room for the conceptual understanding within university physics. Student 2 points out that "*at times it becomes a bit like you learn what's in the books, learn to calculate and solve exercises, but you perhaps don't get to attach it to physical phenomena you can observe*". S3 continues: "*You sit there at the quantum lecture, and go through an hour of calculations, and you get something, and then - you got, the math is ok, you understood every step, but pfff - what happened here, like? What did we figure out?*"

Student 4 sums the sentiment up with "*you have to understand it up against nature. If it's just symbols on a paper and you don't even know what it means, what the result is for the world around it, then I actually don't have much interest anymore.*"

The Master level students thus share the dual view on popular science seen in literature: Motivating, yes - learning, more doubtful. At the same time, they experience a lack of conceptual discussions in calculation-dominated physics classes.

3.3 A possible connection

From one of the interviewed first-year students, we however get an example of how popular science perhaps could have a positive role in learning physics, at a university level. Here we see students having an aha moment when they link learning to previous knowledge, given by popular science:

“*At upper secondary… Yes, I had some aha-moments. They’re not as big as here at university, I feel. But my aha-moments are often that I think something is very cool or that I have heard about something, and then I finally learn about it.*” He then goes on to explain how popular science can give these aha-experiences in later education: “*For example, this relativity with Einstein, not that I understand it completely, but that I have gotten to hear something about it, learn something about it, then I think it’s very exciting and I get that aha-experience.*"

Being primed by popular science and then learning (more) about something can thus create motivating effects. If the perceived gap between popular and "school” physics can be overcome; this then discloses a role in learning popular science. By priming the students and giving an overview of a field of research, students can connect what they learn in classrooms to a wider map of knowledge.

4 SUMMARY

Physics students have self-driven motivation to read popular science beyond what is communicated in media and movies. Our physics students repeatedly turn to popular science for motivation, as an active way of regulating motivation. In this sense, popular science will fit well as it is usually not a part of a curriculum and will be something students autonomously choose to pursue on their own. They find popular science and popular science lectures motivating. A motivating part might be that it might reactivate the goals of becoming a physicist.

We have seen that both academics and students have a dual view of popular science. While it is highly motivating, its’ learning effects are doubted. Both earlier research and students interviewed in this paper, often describes a calculation-driven university physics education. They call for increased attention to conceptual understanding, which connects the mathematical physics to the world it’s meant to describe. One of the questions we thus would like to put forward based on these data is whether the gap between the mathematical and conceptual is an important reason for the perceived gap between “popular physics" and “school physics”.

Conceptual understanding is an important part of physics, and in cases where this is being neglected, it should be given more room. This should diminish the gap between calculation-oriented university physics and conceptually oriented popular physics. If this is successful, could popular physics then be a tool for increased conceptual understanding and a better overview of the field in university physics?

We believe the results from these different surveys prompt the idea that this question should be taken more seriously and suggest that there is a possibility of more conscious use of popular science even at the university level. We believe there are possible paths for popular science to contribute to learning, and in addition, popular science brings forth a motivational factor sorely needed by some students when facing a perhaps solely calculation-oriented university physics education.

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