ENGAGING STUDENTS ORIENTED TOWARDS USEFULNESS IN A BILDUNG-ORIENTED ENGINEERING EDUCATION

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ABSTRACT

In the context of engineering education, there has been a turn toward seeing the future engineer as an agent in society, resolving perceivingly more complex problems, often in cooperation with representatives from other professions. Simultaneously, this more system-perspective and citizen-oriented turn in engineering education connects the education closer to the idea of Bildung, where students are expected not only to become practitioners of a craft, but also active participants in society. This paper discusses the contentious relationship between the concepts of Bildung and usefulness, where a theoretical discussion contrasting different traditions and forms of Bildung is illuminated by datasets from 1700 1st year bachelor engineering students across four consecutive years and these students' motivations toward Bildung-oriented topics. The students' profession-oriented motivations and orientation toward usefulness suggest that a Bildung-oriented education based on the idea that there is a conflict between usefulness and Bildung will be unsuccessful in motivating these students to engage themselves in society. An education for engineering Bildung should thus be based on integrating the ideas of usefulness into the concept of Bildung.

KEYWORDS

Bildung, Systems perspective, Usefulness, Standards: 1, 2, 4

INTRODUCTION

The relationship between engineering and Bildung has long been contentious, and by some even seen as contrary. According to Sjöström et al. (2017), Wilhelm Von Humboldt maintained that language was the main manifestation of Bildung, and due to his influential position in academia, this led to the dismissal of the natural sciences' contribution to Bildung, for the benefit of the humanities. Towards the end of his influential 1999 book on Bildung, Dietrich Schwanitz e.g. describes two high school sweethearts, Sabine and Torsten who plan to get married after their studies. Sabine goes to Hamburg to study psychology, German, and art history, while Torsten moves to Aachen to study mechanical engineering. While Sabine gains insight into the foundations of communication and the symbolic systems of culture and is transformed as a person, Torsten learns how to build machines. When they meet again after their studies, Sabine thinks Torsten sounds like a Neanderthal and breaks off the engagement (Schwanitz, 1999).

This reflects a view where the practical knowledge of the engineer is presented as the antithesis to Bildung, and as we will see this view is rooted in a deeper view within some traditions of Bildung where notions of utility and usefulness are seen as conflicting with Bildung.

Other traditions, however, see it differently, and within more recent reforms of engineering education in several countries, Bildung-oriented views have been very present.

THEORY

In the context of everyday higher education, the concept of 'usefulness' seems to be associated with the expectation of a certain skill or piece of information to be applicable or relevant in future professional contexts. What is perceived as 'useful' for an engineer is dependent on the perceived roles engineers will have in society. A common perception of the world our engineering students are part of and eventually will enter as professional agents could be described as a social world of complexity, in terms of problems, interests, the pace of change, and consequences, a world which Elmose and Roth (2005) describe as a risk society. This description resonates with recent policy documents on engineering education (UHR, 2020). In this perspective, resolutions to problems are the results of collaboration among professionals from different disciplines – real-world problems are rarely resolved by representatives of one discipline, let alone individual representatives (Grasso, Burkins, Helble, & Martinelli, 2010). This perspective implies that the scope of what is considered useful or relevant for an engineer is extended, which in turn calls for several engineering 'profiles', as described by Kamp and Klaassen (2016). Examples of this extension are ethical, aesthetical, economic, environmental, and sustainable considerations.

To get a better grasp of the concept of Bildung, and where a Bildung for engineers can be positioned, we can look both at different traditions and forms of Bildung from previous scholarship. Bildung is a concept that can be hard to define concisely, but many descriptions connect the term to education making not only professionals who are skilled at their craft but also active and engaged citizens (Adler, 1952; Klafki, 2016), contributing with their professional expertise for the betterment of society. This account of Bildung fits well with the perception of the role of our future engineers. Bildung and an extended notion of usefulness seem to coincide in this perspective. However, this relationship has historically been contentious, as we will discuss below.

Building on previous work by Gustavsson (Gustavsson, 2012, 2014) and Burman (2011) Sjöström et al. (2017) describes five traditions of Bildung: 1) a *classical Bildung* based on the ideas by Willhelm Von Humboldt, which is described as a process where the individual develops through education, 2) an Anglo-American tradition of *liberal education*, where humanism and generalization are central values, often associated with a classical canon of topics, 3) the less academically oriented Scandinavian *folk-Bildung*, which focused on a Bildung for all citizens, not just for the formally educated, 4) a *democratic education*, which also focused on the collective aspect, albeit towards formal schooling, and 5) a *critical-hermeneutic Bildung* or *Allgemeinbildung*, which share similarities with folk-Bildung, i.e., Bildung for all citizens, with an explicit emphasis on Bildung in all human capacities.

One of the first things to notice from this initial summary is a progression from emphasizing Bildung as an individual process of emancipation, to seeing Bildung as a collective process both of emancipation, but also toward the betterment of society. The latter is in line with current ideals within Norwegian engineering education, calling for an engineering education that e.g. "facilitates the interaction between ethics, environment, technology, individual and society" (UHR, 2020, p. 28), and with the expected development of the future of engineering education internationally (Graham, 2018, p. 43).

In addition, we can separate ideas about Bildung in different forms. Wolfgang Klafki, in an influential paper from 1959 (updated in 1979), describes a difference between *material* and *formal* theories of Bildung (Klafki, 2001). The material theories deal with the contents of Bildung, i.e., knowledge and skills. In contrast, the *formal* theories concentrate on the person that is going through a process of Bildung. These two theories can also be connected to the contemporary educational philosophies of essentialism and progressivism, where the former, like material theories of Bildung, are curriculum-oriented, while the latter concentrates on the formation of the student, similar to the formal theories of Bildung. Up against both these two theories, Klafki sets his concept of *categorical* Bildung, in which the individual and the world simultaneously open themselves up to one another (Klafki, 2001, p. 193). Sjõstrõm et.al. (Sjöström et al., 2017) on the other hand complements these two theories with reconstructionism, shifting the focus of a Bildung-oriented education toward the effects a knowledgeable student can have on society through critical citizenship. This is in line with a perspective from Jon Hellesnes, describing Bildung as the process of connecting the professional language to the everyday language, specifically the language of politics (Hellesnes, 1992).

Bildung and utility

Using the framework described above, we can combine the traditions and forms of Bildung as a theoretical framework, while discussing diverging views on Bildung and utility. As described by Sjöström and Eilks (2017), Classical Bildung is primarily concerned with the emancipation of the individual, and can thus be seen as formal Bildung, following Klafki's categorization (Sjöström & Eilks, 2020). As such, classical Bildung does not refer to utility.

The American "Great Books"-tradition is part of the *liberal education* tradition and can be seen as a *material* theory of Bildung. This tradition is deeply connected to the idea of a *canon* – a list of *great books* every educated person should be familiar with (Liedman, 2001) which stands in contrast to vocational competence, and by extension to usefulness.

To the Scandinavian folk-bilders on the other hand, there was no conflict between Bildung and practical vocational knowledge. It was exactly the practical applications that made the natural sciences a popular arena for folk-Bildung. A Norwegian edition of the Swedish "Textbook in the Natural Sciences for Elementary Schools and Elementary School Teachers Seminars" by Nils Johan Berlin sold over 40 000 copies over the first 4 years from 1853 onwards. In comparison, the first complete Norwegian bible translation from 1854 had the first printing of 6000 copies (Roos, 2017). The reason for this popularity was exactly its utility in a general population largely living off and from nature. That the utility from the technical and natural sciences form a gateway and a motivation toward Bildung and learning to read is more important to the folk-bilders than exactly what is read, points to this being a more *formal* tradition of Bildung, using Klafki's terminology.

Bildung and engineering: two conflicting ideas

There have been several attempts to include Bildung in engineering education. One such example comes from Axelsson (2009) who describes the historical development of Bildung-oriented topics in engineering education at Chalmers University, Sweden. Chalmers started by teaching technical subjects with a societal connection (e.g. "Technical knowledge - increased security"), later moved in a more general humanistic Bildung direction, and finally moved toward a system perspective of engineering (p. 230).

The initial development points to two competing perspectives: Should the Bildung aspects of engineering education lead to a general humanistic-social science-oriented Bildung, or should they help to give engineers a system perspective on technology? (Axelsson, 2009, p. 225). This discussion partially mirrors the discussions of the "great books" and the "Scandinavian folk-Bildung" traditions, as the more general Bildung perspective does not imply utility for the engineer, while the system perspective does.

We can thus see a duality in the view on the relation between Bildung and usefulness not only in theories on Bildung but also in the concrete attempts to create a Bildung-oriented engineering education.

Consequences for engineering education

For a Bildung-oriented engineering education to be successful, it must dip into engineering students' existing motivations that are centered around different forms of utility, like the Scandinavian folk-Bildung tradition. This would be in line with the system perspective described at Chalmers (Axelsson, 2009). Such a perspective, being more overarching, can integrate the general Bildung perspectives with the professional utility in a better sense than the more limited technical subjects with societal connection.

Creating a curriculum that at the same time seems useful to students and thus motivates them and makes them open up to the ideas in this curriculum, which then again transforms them and changes them as human beings, parallels the processes from the Scandinavian Folk-Bildung tradition, but also points toward something similar to Klafki's idea of *categorial Bildung* (Klafki, 2001). Integrating this idea of utility would then be a key to success in Bildung-oriented engineering education.

METHOD

The data in this study has been collected from 1st-year bachelor engineering students through an open question on why they have chosen their field of study. It has been collected at the start of the course "Introduction to the engineering profession" from 2019 to 2022, slightly into the students' first semester.

The data consists of open-text responses that vary in length from single-word responses to a few short sentences, and these have been categorized using thematic analysis (Braun & Clarke, 2006). The open-text responses were coded thematically, and the relative frequency of the different themes was then registered quantitatively.

All responses have been collected by the online student response systems iLike (2019-2021) and Mentimeter (2022), in a combination of online or live classes (2019) or online classes (2020-2022). Note that the wording of the question was slightly changed from 2019 to 2020 (to compare with another student group) from "Why do you want to become an engineer?" to "Why do you want to study engineering?". This must be kept in mind when analyzing the data, and in coding it has affected the interpretation of e.g. single-word responses like "interesting" or "cool" when it comes to connecting these to interest to "subject" or to "job". The brevity of each data point also led us to chunk responses into relatively large categories, which contain both explicit and implicit responses which we inferred to pertain to a certain category. This process is described more in detail in the Results section. The wording of the questions did not seem to have any notable effects when coding other themes. Upon examining the data we have decided to include the 2019 data as well as the results align well with those from other years.

RESULTS

Overall, we can see from Table 1, engineering students have a strong interest in both the subject of engineering, but most of all their future profession as engineers. While there is also a significant job-related extrinsic motivation, the theme combining practical, useful, creative, and future-oriented elements (explained below) is of similar strength, however, slightly declining over time.

There is also a strong altruistic motivation among engineering students, which however also has a slight decline over the four years. In addition, we see several less prominent, but recurring forms of motivation registered in Table 1, and described in more detail below.

Table 1. Frequency of coded themes from the answer to "Why do you want to study engineering?" over different years. The frequencies show what proportion of respondents gave responses in line with the different themes.

Year	**2019 (N=427)**	**2020 (N=490)**	**2021 (N=399)**	**2022 (N=384)**	**Total (N=1700)**
Interest subject	.25	.51	.42	.29	.38
Interest job	.40	.32	.55	.55	.44
Intrinsic altruistic	.28	.19	.12	.09	.17
Extrinsic	.34	.35	.26	.35	.33
Previous education	.06	.11	.09	.07	.09
Challenge	.09	.06	.06	.04	.06
Create, develop, build	.33	.19	.23	.15	.22
Useful	.2	.11	.08	.05	.09
Future	.15	.12	.15	.09	.13
Practical	.08	.13	.07	.06	.09
Create+Useful+Practical+Future	.44	.36	.36	.24	.35
Understanding	.03	.01	.04	.02	.02
Varied work	.07	.05	.10	.05	.07

We have separated the students' intrinsic motivation into a category for interest in and enjoyment of the subjects the students are studying, and another for interest in and (perceived) enjoyment from the job or the profession they envision themselves moving into after their education. These two can however sometimes be hard to discern when students simply respond with "interest", "exiting" etc. without explicitly connecting these motivations to either. In addition, we have the category "Intrinsic altruistic" which describes different motivations for contributing to society (typical examples are helping with the climate crisis, developing technology to improve society, etc.).

In categorizing Extrinsic motivations, external consequences of both the education and possible job are included, like status, salary, but also a secure job, "many possibilities", just getting an education or influences from external actors like family.

In categorizing "Previous education", all references to previous education as motivation have been included like experiences of mastering these topics in upper secondary education or viewing engineering as a natural next step after a vocational education, possibly also after a period of employment. One illustrative example of the latter is: "As an electrician, I've been wanting to expand my knowledge by going to uni - so electrical engineering seemed like a great option."

In categorizing "Challenge" both explicit references to wanting to "challenge" oneself are included, but also some more general comments on wishing to develop oneself that allude to challenging.

In categorizing Creating, both references to "creating", "developing", "building", "forming" and some slightly more general references to creativity and shaping are included.

There is naturally some overlap between this category and the "practical", but both the more general references and the development of e.g. computer programs that are not considered as "practical" in a more physical sense, create a difference. On the other hand, in the "practical" theme some references to an education and/or profession that is more practically oriented will not be included in the "creating" category.

In categorizing usefulness, both explicit references to "usefulness" and e.g. descriptions of "problem-solving" have been included.

In the theme "future" references to their education being future-oriented is notable, but other references to the future are also included, including uses of “new” (e.g. creating something new, previously unseen) and similar terms pointing to the future.

In categorizing the theme "practical", both explicit references to practical work and references to creating/developing concrete "things" have been included. Some students emphasize the balance between theory and practice, e.g. “a good mix between theory and practice, I doubt I’ll ever get tired of it”.

In addition, we register all students with responses within the four last categories from an interpretation that these responses are often connected to a certain view of engineering, e.g., creating something practical for the future is useful. This is a relatively common theme in the responses, we can also see that of a total of 599 students who in brief responses have been assigned one of these themes, 250 have had at least one of the others assigned as well.

Examples of students expressing a combination of these motivations can still be brief and compact: “to find solutions to practical and future problems”, “Creating something new and contributing to technological development” etc.

The theme “understanding” mainly consists of a wish to understand (more about) how different technologies or technological objects work.

The theme “varied work” consists to a large part of the idea of a varied future workday, but also the more overarching idea of a multitude of work possibilities. In many responses, this is connected to the lack of this in a current job after vocational education, e.g. “With my vocational degree I am more or less locked to one position, but as an engineer, I can work in many fields.”

DISCUSSION AND RECOMMENDATIONS

There are reasons to be wary of making strong conclusions on development over time in the student group. One element is the slight change in the wording of the question from 2019 to 2020. Another is the change in setting from a mix of online and physical lectures to only online lectures for collecting data. Finally, there was a change in the response system used to collect the data from 2021 to 2022. Although the form of response was identical, the different user interface and experience of the system might still have subtle influences on the students’ responses. Only in 2020 and 2021 have the data thus been collected in a completely identical manner. For these reasons, we will mainly discuss the total results from these four years, where the data are more robust, and not the more subtle changes between years.

Regarding our main topic of utility, we see that despite the decline over the four years, there is a strong overall motivation in engineering students toward the practical, concrete, and useful, including contributing to society both in concrete areas like climate change, but also more generally in contributing to technological development. The idea of something being useful here clearly has a broader impact than the concrete references to usefulness included in the “useful” theme itself. Building, creating, and contributing to technological development is a central motivation for engineering students. This could be used as leverage for integrating Bildung perspectives in engineering education.

The spectrum of expressed motivations among the students does, however, put some restraints on how this can be integrated. In utilizing a definition of Bildung that connects students and their profession to society, we can see that the elements we have to build upon from the students' motivations go from the altruistic "contribute to fighting the climate crisis through developing renewable energy" to the more purely technology-oriented "contributing to developing new technology" to the more generic "problem solving" and to the wish to develop concrete new products and solutions. It should be noted that expressed motivations like "problem-solving" might not bear any reference to society, but rather reflect an intrinsic interest in solving problems. Nevertheless, as resolutions to technological problems are inevitably linked to society, we can utilize the educational context of engineering education to include both intrinsic interest and societal usefulness, thus supporting a systems perspective on Bildung in which utility is an integral part.

We can thus discern a certain taxonomy of utility in students' motivations, from the very concrete useful product, more connected to the colloquial "usefulness" to the more overarching societal perspective which can connect well with a wish to create a Bildung-oriented engineering education. Utility, in one form or another, is thus at the core of engineering students' societal motivations, and an interpretation of Bildung that separates Bildung from utility will be of little relevance to engineering students' existing motivations. One could envision an education attempting to move engineering students upwards in their taxonomy of utility, from building things to contributing to technological development in general toward building and improving society.

As a final note, we will comment on a couple of developments from the results, prominently the decline in altruistic motivations. Could it be that the insecurities from the pandemic and war with consequential economic insecurities have shifted students' focus away from e.g. tackling climate change and more toward securing their future? The extrinsic motivation however seems stable. There is also a decline over time in the "create, develop, build" theme. One could hypothesize that this is a sign of an academization of study programs that until recently were in engineering colleges but then merged into a larger university, away from their practical roots. These data can however not conclude on such questions, but these could be topics relevant for further, more qualitative, studies.

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REFERENCES

Adler, M. J. (1952). *The Great Ideas: A Syntopicon of Great Books of the Western World* (Vol. 1). Chicago, London, Toronto: Encyclopedia Britannica.

Axelsson, A.-S. (2009). Bildning i den tekniska högskolan [Bildung at the engineering college]. In Å. I. K. Wagner & A.-S. Axelsson (Eds.), *På spaning efter teknisk bildning [Searching for technical Bildung]* (pp. 222-241). Stockholm: Liber.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Burman, A. (2011). Svar på frågan: Vad är medborgerlig bildning? [Answer on the question: What is civic Bildung?]. In A. Burman (Ed.), *Våga veta! Om bildningens möjligheter i massutbildningens tidevarv [Dare to know! About the opportunities for Bildung in a time of mass education]* (pp. 9-31). Huddinge: Södertörns högskola.

Elmose, S., & Roth, W. M. (2005). Allgemeinbildung: readiness for living in risk society. *Journal of Curriculum Studies, 37*(1), 11-34. doi:10.1080/0022027041000229413

Graham, R. (2018). *The global state of the art in engineering education*. Massachusetts: Massachusetts Institute of Technology.

Grasso, D., Burkins, M. B., Helble, J. J., & Martinelli, D. (2010). Dispelling the Myths of Holistic Engineering. In D. Grasso & M. B. Burkins (Eds.), *Holistic Engineering Education*. New York Springer New York

Gustavsson, B. (2012). Bildningens traditioner i transformation [The traditions of Bildung in transformation]. In A. Burman & P. Sundgren (Eds.), *Svenska bildningstraditioner [Swedish Bildung traditions]* (pp. 309-327). Göteborg: Daidalos.

Gustavsson, B. (2014). Bildung and the road from a classical into a global and postcolonial concept. *Confero, 2*, 109-131.

Hellesnes, J. (1992). Ein utdana mann og eit dana menneske. In E. L. Dale (Ed.), *Pedagogisk filosofi* (pp. 79-104). Oslo: Ad Notam Gyldendal.

Kamp, A., & Klaassen, R. G. (2016). *Impact of global forces and empowering situations on engineering education in 2030.* Paper presented at the 12th international CDIO conference.

Klafki, W. (2001). Kategorial dannelse : Bidrag til en dannelsesteoretisk fortolkning av moderne didaktikk. In E. L. Dahle (Ed.), *Om utdanning : Klassiske tekster*. Oslo: Gyldendal Norsk Forlag.

Klafki, W. (2016). *Dannelsesteori og didaktik - nye studier*. Aarhus: Forlaget Klim.

Liedman, S.-E. (2001). *Ett oändligt äventyr – Om människans kunskaper*. Stockholm: Albert Bonniers Förlag.

Roos, M. (2017). Naturvitenskap som dannelsesprosjekt. In M. R. J. Tønnesson (Ed.), *Sann opplysning? Naturvitenskap i nordiske offentligheter gjennom fire århundrer*. Oslo: Cappelen Damm Akademisk.

Schwanitz, D. (1999). *Bildung : Alles was man wissen muß*. Frankfurt an Main: Eichborn Verlag.

Sjöström, J., & Eilks, I. (2018). Reconsidering Different Visions of Scientific Literacy and Science Education Based on the Concept of Bildung. In Y. J. Dori, Z. R. Mevarech, & D. R. Baker (Eds.), *Cognition, Metacognition, and Culture in STEM Education: Learning, Teaching and Assessment* (pp. 65-88). Cham: Springer International Publishing.

Sjöström, J., Eilks, I., & Talanquer, V. (2020). Didaktik Models in Chemistry Education. *Journal of Chemical Education, 97*(4), 910-915. doi:10.1021/acs.jchemed.9b01034

Sjöström, J., Frerichs, N., Zuin, V. G., & Eilks, I. (2017). Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning. *Studies in Science Education, 53*(2), 165-192. doi:10.1080/03057267.2017.1384649

UHR. (2020). *Nasjonale retningslinjer for ingeniørutdanning [National guidelines for engineering education]*. Oslo: Universitets- og høgskolerådet Retrieved from https://www.uhr.no/_f/p1/i3f80bc0d-b1b6-4334-bf25-7571488e9612/nasjonale-retningslinjer-for-ingeniorutdanning-vilkar-for-siving-vedtatt-nov-2022.pdf

BIOGRAPHICAL INFORMATION

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