Bridging the Gender Gap through Problem-Based Learning in STEM Labs: What can we learn from Biotechnology?

Lykke Brogaard Bertel
Department of Planning
Aalborg University
Aalborg, Denmark
lykke@plan.aau.dk

Mette Møller Jeppesen
Faculty of Engineering
Aalborg University
Aalborg, Denmark
mmje@adm.aau.dk

Lars Bo Henriksen
Department of Planning
Aalborg University
Aalborg, Denmark
lbh@plan.aau.

Søren Hansen
Department of Planning
Aalborg University
Aalborg, Denmark
sha@plan.aau.dk

Bettina Dahl
Department of Planning
Aalborg University
Aalborg, Denmark
bdahls@plan.aau.dk

***Abstract*— This Research to Practice Work-In-Progress paper introduces LabSTEM North, a Danish design-based research project, which aims to explore central and contextual issues related to diversity and motivation in STEM and to co-create an integrated problem-based STEM-didactics with K-12 teachers across institutional and disciplinary boundaries in the Northern Region of Denmark. The paper presents the reasoning behind and initial phases of the project, its research design and methods and presents preliminary findings from a case study on biotechnology as an example of a subject and engineering program particularly successful in attracting young women to STEM. Interviews with students from general high school, technical high school and 1st year university point to the inherent 'meaningfulness' of health-related subjects as a particularly motivational factor for education and career choices. This highlights the importance of 'meaning' and exemplarity in the content, context and complexity of the chosen 'problem' in problem-based learning. In the LabSTEM North project, these insights will inform the cross-institutional co-creation of problem-based and STEM-integrated teaching, emphasizing attention to the choice of meaningful problems to support diversity and motivation for STEM.**

Keywords—Problem-based learning, Project-based learning, K-12 STEM education, Gender, Diversity

I. INTRODUCTION

The gap between the need for and the number of STEM-educated individuals is becoming increasingly apparent, both globally [1-2] and locally in areas such as the northern region of Denmark, which has seen a rise in need for STEM competencies of 88% over the last decade, with companies in the region facing severe difficulties in filling open and planned future positions [3]. Additionally, research shows declining interest in STEM-related disciplines starting as early as ages 11-15 [4-5], contributing further to the problem and pointing to the need for new inquiries and recommendations for increasing interest and diversity in engineering educations and professions [6-7]. Especially girls tend to lose interest in STEM during grades 4-8, which indicates that new approaches are needed to motivate and engage this student group and convey the possibilities related to STEM-education and career paths [8-9]. Thus, it is crucial to examine global and local factors causing this gender gap and lack of diversity in STEM, as well as to develop didactical practices and collaborative efforts across disciplinary and institutional boundaries to facilitate motivation and diversity in STEM and to support teaching innovations that challenge traditional 'single silo' thinking and support the acquisition of relevant competencies for the 21st century [10-12].

Problem-based learning (PBL) is a student-centered approach to teaching that offers students the possibility to engage in interdisciplinary and experiential learning. This approach is increasingly integrated into educational contexts in both K-12 and engineering education [13-17], in some cases with specific focus on how to increase diversity and gender equity [18-19]. Key features of PBL include working with real-life problems with an emphasis on self-directed and collaborative learning, which can lead to the transformation of students' perception of and approach to complex problem solving [20]. Another common principle of PBL is exemplarity; meaning that problems and solutions resemble and serve as good examples of the students' future profession [21-22]. PBL has been shown to be efficient as a tool and framework for didactical interventions within a STEM context, particularly in higher education, however research on what aspects of PBL facilitate motivation for STEM in K-12 is still rather limited [23].

This paper presents preliminary findings from a case study on biotechnology, which distinguishes itself from other STEM-programs in its ability to attract particularly young women to the field, exploring what contributes to the students' motivation. The case study is part of LabSTEM North, a Danish research and development project that aims to explore key and contextual issues related to diversity and motivation in STEM and to co-create a problem-based STEM-didactics with K-12 teachers across institutional and disciplinary boundaries in the Northern Region of Denmark. In the following, we present the LabSTEM North project, its connection to related projects, research design and methods and outline the context for the case study in biotechnology. We present findings from the analysis of 13 interviews with female biotechnology students from high school (STX), technical high school (HTX) and 1st year university, as part of this case study. Results indicate that the principle of exemplarity and a sense of 'meaning' are key components for facilitating motivation in problem-based learning. Finally, the implications of these findings are discussed in relation to the

efforts to promote STEM interest and motivation in the project LabSTEM and in K-12 STEM education, in general.

II. The LabSTEM North Project

LabSTEM North (2021-2024) is a three-year research and development project involving the collaboration of more than 80 K-12 teachers in the Danish region of Northern Jutland [24]. The purpose of LabSTEM North is to create a framework for problem-based and STEM-integrated teaching and to support interdisciplinary and cross-institutional collaboration on the development of educational designs applicable and adaptable to different educational contexts. Through the development of inspiring and engaging learning experiences and teaching material, the project aims to increase student motivation in STEM and eventually the number of aspiring STEM graduates in the region.

The LabSTEM North project is inspired by and collaborating with a similar effort in the southern region of Denmark, focusing on the integration of Mathematics in STEM-teaching through a *STEM laboratory model* [25-26]. In LabSTEM North, the focus is STEM-integrated teaching, i.e., incorporating a minimum of two or more STEM subjects, and the STEM lab model for professional development is transformed into a '*virtual'* or *'hybrid'* STEM lab model, providing flexible and free access to workshops, digital resources, and teaching materials [27]. What distinguishes LabSTEM North is its focus on PBL as a set of educational principles and a foundation for developing interdisciplinary and vertically integrated STEM-teaching at all levels of education. This includes both students, teachers, management and stakeholder perspectives in the project to link learning goals, local contexts, professional practices and student motivation in K-12 and higher education transitions in the LabSTEM North research design.

III. Research Design

The research design in LabSTEM North is inspired by Design-Based Research (DBR) [28]. In DBR, contextual understandings and incorporation of multiple iterations of designs for change in collaboration with stakeholders are considered essential to support a holistic and contextually embedded process of transformation based on and contributing to new theoretical knowledge [28-29]. Through an iterative process of intervention, experimentation, and adjustment of knowledge to and with practice, researchers and teachers in K-12 STEM collaboratively explore, develop and refine practice-based designs and theory [29]. In this sense, DBR has much in common with PBL as both seek to establish domain-specific knowledge and discover complexities that guide the identification of problems, experiences, contextual factors, and relevant socially sustainable solutions. Thus, prior research has also highlighted the potential of DBR to further mature PBL research and practice, providing theory-informed insights into why PBL with certain characteristics work in specific contexts with particular goals in mind [30].

The project is organized around five interconnected activities, each incorporating different qualitative and participatory methods. First, a preliminary case study on local current and best practice within STEM-teaching is conducted, including a study on biotechnology as an exemplary case (A1). This case study feeds into the co-creation of a theoretical framework for problem-based and STEM-integrated teaching. This framework is further elaborated and refined in close connection with the ongoing exploration and experimentation in practice (A3). Alongside this iterative process, a conceptual model for collaborative teacher communities in virtual STEM labs is develop and tested (A4). All activities are continuously disseminated in relevant local, national, and international research and practice communities, e.g. through the development of online resources and open-access teaching materials (A5).

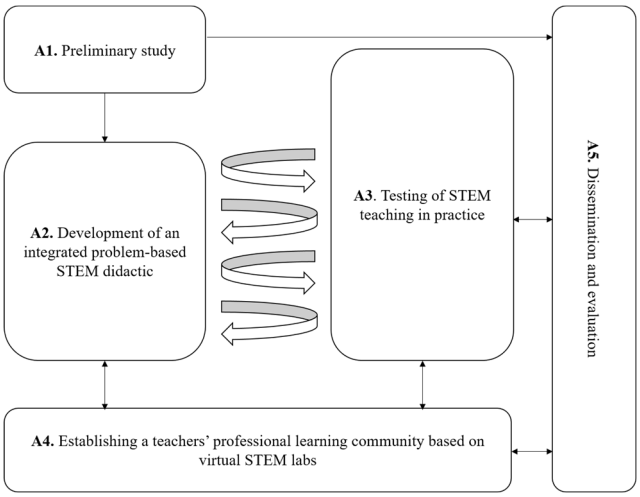

Fig. 1. Design-based research activities in the LabSTEM North project [27]

As the project launched mid 2021, the first year has focused primarily on recruiting K-12 schools and teachers to LabSTEM and on establishing virtual STEM labs to test out in practice (A4). Furthermore, the pre-study of local existing and best STEM practices (A1) has commenced, including the case study on biotechnology. The idea is that findings from this case study will feed into the project by providing input for the development of a problem-based STEM didactics (A2), which will be tested and further developed (A3) in 2022-2023.

IV. Case study: Biotechnology

As DBR allows for and emphasizes continuous reflection on and adaption to potentials, challenges, and critical issues in practice to improve theories, methods and designs, practicing awareness and reflexiveness is crucial in all stages of the project. Thus, theory, practical knowledge and collaborative reflection on initial research questions in the early stages of the LabSTEM North project are used by both researchers and teachers to improve areas of current project processes.

One such research question centers on the success of biotechnology as a subject and STEM program particularly successful in attracting young women to the field. Previous studies have shown how 'newer' engineering professions such as biotechnology and biomedical engineering have increased diversity in engineering education, especially with regards to attracting women [19], highlighting the social context and perceived 'social good' of these disciplines as particularly motivating for some students [31]. Similarly, establishing biotechnology electives or 'tracks' in upper secondary education in Denmark, have increased the intake of girls in technical high school (HTX) and the number of girls with STEM-profiles in general high school (STX) [32]. However, whereas biotechnology to some student groups is clearly considered more attractive than other STEM subjects, programs and careers, it is unclear why this is the case; what other STEM subjects might learn from biotechnology with regards to student motivation and how this motivation could be facilitated through the entire educational system.

Related research indicate that previous interest in STEM subjects can contribute to motivation for choosing to enrol in a STEM program, however on the other hand, school activities designed specifically with the purpose of promoting interest in STEM might be experienced as intrusive and decrease intrinsic motivation [33]. In a similar vein, potentials of out-of-school labs and informal learning to promote interest in biotechnology have previously been highlighted, emphasizing particularly students' perceptions of autonomy and competence as determining factors for intrinsic motivation in the subject [34]. As the biotechnology subject in Danish technical and general high school is known to incorporate PBL and student-centered learning methods emphasizing autonomy and self-directed learning, this case study was initiatied to explore whether PBL is perceived as a contributing factor to the students' motivation for biotechnology and if so, whether and how PBL can serve as a non-intrusive alternative to activities designed to promote interest and motivation in other STEM subjects as well.

A. Context for the case study

As the Danish labour market and education sector constitutes the context for the case study, it is relevant to provide a brief overview of the current state of diversity and gender equity within this particular context. Historically, there has been an uneven gender distribution within the Danish labor market with men generally working with technology, trade, science, and crafts, in the private sector and women working within education and health, in the public sector [35]. A similar gender distribution is found in many other European countries with a distinct divide between 1) science and humanities and 2) care and technical orientation making up more than 90 percent of gender distribution in the labour market [36]. Gender patterns in society tend to replicate in higher education, thus having an impact on young peoples' educational trajectories and occupational aspirations, further solidifying these gender differences. Thus, similar gender-patterns are found even as early as upper secondary education in Denmark, with girls accounting for 61% of students in (STX), 41% of students in commercial high school (HHX) and just 26% of students in HTX [37]. However, some HTX schools have managed to attract more girls in recent years – in some select cases as many as 49% to 65% - by offering new study programmes in design and biotechnology [32].

B. Data collection and methods

As HTX is also known for implementing PBL models in all their programs [23], and STX is increasingly incorporating PBL methods in biotechnology electives and other STEM subjects, we wanted to understand whether this pedagogical approach is in any way a contributing factor to the students' motivation for biotechnology and if so, what factors should be considered when implementing PBL methods to support interest and motivation in STEM subjects in general. Thus, in the summer and fall of 2021, interviews were conducted with female students from upper secondary school (HTX and STX) studying biotechnology as well as with female 1st year university biotechnology students. We applied a thematic analysis to the case study [38-39], analyzing the narratives presented in interviews with students.

Thus, the interviews all took point of departure in an open interview guide centered around questions related to motivation for choosing biotechnology as a field of study, with the subjects biology and chemistry at the centre. In addition, the interviews revolved around their experiences studying biotechnololgy and particularly motivating aspects of the study as well as their expectations with regard to future choice of studies or career paths. The interviews were transcribed and analysed thematically.

	Data Collection		
		No of interviews	***Study direction***
1	Technical high school	5	Biotechnology A
2	General high school	4	Biotechnology A
3	1st year university	4	Biotechnology

Fig. 2. Overview of interviews

V. PRELIMINARY FINDINGS

In the following, we present findings from the interviews with high school students from HTX and STX and 1st year university, focusing on 1) their motivation for choosing biotechnology, 2) their experience of PBL in the subject or programme and 3) expectations regarding future education or career.

A. Motivation to study biotechnology

When asked about their motivation for choosing biotechnology as an elective or 'track', several students at both HTX and STX pointed to a career within the health sector as a key motivator e.g.: *'I have always wanted to study medicine and become a medical doctor, so biotech was the obvious choice'* and *'I knew I wanted to study medicine and therefore I chose mathematics at A level, as it is an entry requirement to medical school'*. This underlines how the subject of biotechnology manages to make core STEM subjects like mathematics motivating or at least acceptable as a 'necessary evil' to reach the goal of working within a specific field, however potentially also continuing rather than challenging the existing gender distribution in the education system and labor market.

Other HTX and STX students mentioned previous positive experiences with STEM subjects as a key motivating factor. Both students from high school and 1st year college mentioned past experiences with particularly encouraging teachers, e.g. from biology in primary and lower secondary school or high school: *'a really good teacher who managed to make the subject interesting'*. Other students emphasize personal competence within the STEM subjects, e.g.; *'I was good at physics and mathematics in primary school'*. One college student explained how she had always been proficient in the natural sciences and whereas biology was the initial motivator, when she started chemistry she thought it was interesting as well and became aware of biotechnology as a field of study through this. Other high school students specifically described biotechnology as an 'opt-out', e.g. from a specific family identity or tradition; *'I just knew it was going to be science, all the rest of my family have studied humanities, but I wanted something to do with science'* or from specific (social science or humanities) subjects; *'I knew I was not supposed to study subjects such as German language or social science, so, biotech ended up beeing the better choice'*.

Some high school students emphasized long-term perspectives such as the broad access to different educations that biotechnology provides as particularly motivating for their choice of study, whereas others highlighted specific introductory activities such as an 'open day' event at the high school or the introductory week as particularly important for

their initial interest in and ongoing motivation to study biotechnology, e.g. *'After trying out different fields of study in the introductory week, I got more interested in biotechnology. It turned out to be very exciting, and I have never regretted it'* and *'You get to try some things and can make a better choice. It made me confident in my choice of biotechnology'.*

B. PBL and 'meaning' in biotechnology

Some students emphasized biotechnology as a subject where the alternation between experimentation, report writing and classroom teaching was done successfully; *'Report writing is fine because it all just falls into place when you sit and write'* and '*The practical experiments make it all more exciting, and it all just makes a lot more sense'.* The experience of a subject 'making sense' or being 'meaningful' was hightlighted by all of the students. E.g. chemistry becomes meaningful when used in conjunction with biology to provide insight into problems and experiments. PBL contributes to this, as the project work provides a boundary object for the subjects to interact in a meaningful way. For instance, one highschool student mentioned how she felt that biology- and chemistry teachers separately had difficulties integrating their fields into biotechnology in meaningful ways but that experiments and project work could remedy the division of the subjects. Several students also highlighted the SRP project (an interdisciplinary capstone project in the third year) as a particularly positive experience. 1st year college students mentioned how collaborating with others through project work was motivating and how PBL was a way to work with subjects such as biology and chemistry in 'realistic' and very diverse ways; *"The best thing about biotech is that it is a very broad field, projects can go in many different directions (...) there is always development. You can stay with your interest in one theme (e.g. enzymes) for longer or go in new directions."* Several 1st year college students mentioned PBL as specifically motivating for their choice of university, as they already had experience with project work from HTX.

C. Future education trajectories and career paths

When asked about expectations towards future education and career paths, the majority of the highschool students mentioned medical studies as their main priority. One student who also stated medicine as the preferred field of study added *'psychology, medicine, pharmacist or something like that'* and another student mentioned nursing, reiterating the focus on health and care mentioned earlier. Only one student mentioned engineering, adding *'(...) but there are so many different engineering directions, so it is not at all easy to figure out'*. Interestingly, biotechnology or biomedical engineering were not mentioned as a desired future education or career for this group. This could indicate that for many of the students, the choice of biotechnology as a subject might be considered more of a means to an end, rather than a potential career path. However, when asked, all interviewees were happy with their choice of the subject. 1st year college students also mentioned that their initial thought was to study medicine, but that their choice fell on biotechnology because it provided some flexible job opportunities and the prospect of reasonable working hours. Some college students also mentioned their experience with project work as an important competency: *"Project management is what you need if you want to work at a company and this way you become good at projects, also in your future career."*

VI. Conclusions and future work

In this Work-in-Progress paper, the design-based research project LabSTEM North was introduced and preliminary findings from the initial phases of the project, including a case study on biotechnology were presented addressing the following research questions; Why is biotechnology as a subject and program seemingly more successful in attracting young women to the field compared to other STEM subjects? Is the PBL approach in biotechnology perceived as a contributing factor to young womens motivation for the subject and if so, how can PBL serve as a non-intrusive alternative to activities designed to promote STEM interest and motivation in other STEM subjects as well?

Firstly, findings from interviews with young women in biotechnology electives or 'tracks' in general and technical high school as well as 1st year biotechnology students indicate that their main motivation for choosing this field of study was the possibility of studying medicine or otherwise entering the healthcare sector in the future. This could indicate that some young women are motivated by *long-term goals* and future career options when choosing electives or 'tracks' in highschool. Secondly, the majority of the young women interviewed mentioned '*meaningfulness'* as central to their choice of and motivation for studying biotechnology. The teaching approaches, learning methods and possible career paths afterwards have to 'make sense' and point towards something meaningful. In connection to this, the young women highlighted the *combination* of disciplines and different learning methods such as experiments, report writing, classroom teaching and project work as particularly motivating and meaningful. Thus, these preliminary findings indicate that PBL can be considered a contributing factor to girls and young women's motivation for the subject of biotechnology, but that the inherent 'meaningfulness' of health and care related subjects is considered particularly motivational for education and career choices for this particular group of students, highlighting the importance of 'meaning' and exemplarity also in subject content, learning methods and choice of 'problem' in problem-based learning.

The LabSTEM North project is currently working to integrate these findings into the iterative development and testing of an integrated problem-based STEM didactics. Here, the case study has provided valuable insights into key motivational factors and future education and career expectations when choosing biotechnology as an elective, track or field of study and highlights central themes when developing problem- and project based learning experiences that aim to decrease the gender gap in STEM, including the importance of relevance and 'meaning' in the addressed 'problem' as well as providing project management competences considered relevant in a future career. In future work, PBL-based STEM-integrated educational design will be developed, tested and evaluated across and in collaboration with different educational contexts and stakeholders. This will further inform the cross-institutional co-creation of problem-based and STEM-integrated teaching in other STEM-fields as well including mathematics, physics, technology, technical science etc. Emphasizing attention to the choice of meaningful problems in PBL as well as students' self-determination with regard to choosing exemplary problems, subject content and suitable learning methods, the goal is to further support diversity and motivation in K-12 STEM and 1st year engineering education.

REFERENCES

[1] National Science and Technology Council, "Charting a course for Success: America's Strategy for STEM Education, " 2018, [online] Available:https://www.energy.gov/sites/default/files/2019/05/f62/STEM-Education-Strategic-Plan-2018.pdf

[2] European Commission. Directorate-General for Education and Culture., Danish Technological Institute., Technopolis Limited., 3s Unternehmensberatung GmbH., And ICF Consulting Services., Does the EU need more STEM candidates?: final report. LU: Publications Office, 2015. [Online]. Available: https://data.europa.eu/doi/10.2766/000444

[3] Region North, "Nordjysk Teknologipagt [red. North Jutlandic Technology Pact]," 2019. [Online]. Available: Nordjysk Teknologipagt (rn.dk)

[4] J. Pleasants, "Inquiring into the Nature of STEM Problems: Implications for Pre-college Education," Sci & Educ, vol. 29, no. 4, Aug. 2020, doi: 10.1007/s11191-020-00135-5.

[5] J. Osborne & J. Dillon. "Science education in Europe: Critical reflections", Vol. 13. 2008. London: The Nuffield Foundation.

[6] Committee on Women's Rights and Gender Equality, "On promoting gender equality in science, technology, engineering and mathematics (STEM) education and careers," European Parliament, 2021.[Online].Available:https://www.europarl.europa.eu/doceo/document/A-9-2021-0163_EN.pdf

[7] CEDEFOP, "2019 Annual Report," CEDEFOP, European Centre For Vocational Training, 2019.

[8] J. K. Naukkarinen & S. Bairoh, "STEM: A help or a hinderance in attracting more girls to engineering?", Journal of Engineering Education, 109(2), 177-193, 2020.

[9] K. Battel, N. Foster, L. V. Barroso, S. Bhaduri, K. Mandala and L. Erickson, ""We Make the Village" - Inspiring STEM Among Young Girls and the Power of Creative Engineering Education in Action," 2021 IEEE Frontiers in Education Conference (FIE), 2021, pp. 1-7, doi: 10.1109/FIE49875.2021.9637322.

[10] T. D. Holmlund, K. Lesseig, and D. Slavit, "Making sense of 'STEM education' in K-12 contexts," IJ STEM Ed, vol. 5, no. 1, Dec. 2018, doi: 10.1186/s40594-018-0127-2.

[11] T. Pierce and R. Winzer, "STEM Outreach: Inspiring the Pre-College Generation," vol. VOl. 61., 2020.

[12] D. Stentoft, "From saying to doing interdisciplinary learning: Is problem-based learning the answer?," Active Learning in Higher Education, vol. 18, no. 1, Mar. 2017, doi: 10.1177/1469787417693510.

[13] J. Chen, A. Kolmos, and X. Du, "Forms of implementation and challenges of PBL in engineering education: a review of literature," European Journal of Engineering Education, vol. 46, no. 1, Jan. 2021, doi: 10.1080/03043797.2020.1718615.

[14] M. C. LaPlaca, W. C. Newstetter and A. P. Yoganathan, "Problem-based learning in biomedical engineering curricula," 31st Annual Frontiers in Education Conference. Impact on Engineering and Science Education. Conference Proceedings (Cat. No.01CH37193), 2001, pp. F3E-16, doi: 10.1109/FIE.2001.963748.

[15] C. Malstrom, "Project lead the way engineering and biomedical sciences curriculum programs engage students and improve performance in STEM," 2011 Integrated STEM Education Conference (ISEC), 2011, pp. 1A-1-1A-4, doi: 10.1109/ISECon.2011.6229632.

[16] L. G. Richards and S. K. Donohue, "Pre-college (K-12) engineering education: Getting Them Early … and Keeping Them!," 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, 2014, pp. 1-4, doi: 10.1109/FIE.2014.7044309.

[17] K. Zeeshan, C. Watanabe and P. Neittaanmäki, "Problem-solving skill development through STEM learning approaches," 2021 IEEE Frontiers in Education Conference (FIE), 2021, pp. 1-8, doi: 10.1109/FIE49875.2021.9637226.

[18] M. Paretti, B. D. Jones, H. Matusovich and J. Moore, "Work in progress — A mixed-methods study of the effects of first-year project pedagogies on the motivation, retention, and career plans of women in engineering," 2010 IEEE Frontiers in Education Conference (FIE), 2010, pp. T4H-1-T4H-3, doi: 10.1109/FIE.2010.5673331.

[19] X. Du & A. Kolmos, "Increasing the diversity of engineering education–a gender analysis in a PBL context", European Journal of Engineering Education, 34(5), 425-437, 2009.

[20] M. Savin-Baden, "Management of change. Implementation of problem-based and project-based learning in engineering", In E. Graaff and A. Kolmos (Eds.) Management of change – Implementation of problem-based and project-based learning in engineering. Netherlands: Sense Publishers, p. 9-29, 2007.

[21] A. Markula and M. Aksela, "The key characteristics of project-based learning: how teachers implement projects in K-12 science education," Discip Interdscip Sci Educ Res, vol. 4, no. 1, Dec. 2022, doi: 10.1186/s43031-021-00042-x.

[22] A. Kolmos & J. E. Holgaard, "Impact of PBL and company interaction on the transition from engineering education to work", In 6th International Research Symposium on PBL: Social Progress and Sustainability, 2017, pp. 87-98. Aalborg University Press.

[23] M. M. Jeppesen, "Technology and problem-based learning - The higher technical examination programme", 2021. Aalborg University Press. https://doi.org/10.54337/aau470870268

[24] "LabSTEM North." 2022. [Online]. Available: https://www.ucpbl.net/research/labstem-nord/

[25] Region South Denmark, "LabSTEM – Laboratorium for integreret STEM-undervisning og læring [red. LabSTEM South - A Laboratory for an integrated STEM-teaching and learning]," Project Overview, 2020. [Online]. Available: https://www.sdu.dk/da/forskning/labstem/laboratorier

[26] B. D. McCandliss, M. Kalchman, and P. Bryant, "Design Experiments and Laboratory Approaches to Learning: Steps Toward Collaborative Exchange," Educational Researcher, vol. 32, no. 1, Jan. 2003, doi: 10.3102/0013189X032001014.

[27] S. H. Christiansen, L. B. Bertel & B. Dahl, "Problem-based learning in STEM: Facilitating Diversity and Change in Pre-college Engineering Education through Online Collaborative Teacher Communities in virtual STEMlabs". In Proceedings of the Annual ASEE Conference, 2022. In press.

[28] T. Amiel and T. C. Reeves, "Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda," 2008.

[29] F. Wang and M. J. Hannafin, "Design-based research and technology-enhanced learning environments," *ETR&D*, vol. 53, no. 4, Dec. 2005, doi: 10.1007/BF02504682.

[30] D. H. Dolmans, "How theory and design-based research can mature PBL practice and research", 2019, Advances in Health Sciences Education, 24(5), 879-891.

[31] A. Kolmos, N. Mejlgaard, S. Haase & J. E. Holgaard, "Motivational factors, gender and engineering education", European Journal of Engineering Education, 2013, 38(3), 340-358.

[32] L. Ulriksen & H. L. Holmegaard, "Rigtige piger går ikke på htx, men piger er glade for at gå der", MONA-Matematik-og Naturfagsdidaktik, (2). 2007.

[33] S. Luttenberger, M. Paechter, & B. Ertl, "Self-concept and support experienced in school as key variables for the motivation of women enrolled in STEM subjects with a low and moderate proportion of females", Frontiers in Psychology, 10, 1242, 2019.

[34] K. Röllke and N. Großmann, "Predictors of Students' Intrinsic Motivation in a Biotechnological Out-of-School Student Lab", Frontiers in Education. Vol. 7. Frontiers, 2022.

[35] Kvindfo, "Et arbejdsmarked støbt i beton", 2016, [Online]. Available: https://kvinfo.dk/et-arbejdsmarked-stoebt-i-beton/

[36] C. Barone, "Some things never change: Gender Segregation in Higher Education across Eight nations and three decades" Sociology Education, 2011-04-01, Vil. 84 (2) p. 157-176.

[37] J. Sandager, & J. P. Grønbæk, "Kønsforskelle i uddannelsesvalg", Samfundsøkonomen. 1, 2020.

[38] B. Flyvbjerg, "Five misunderstandings about case-study research" Qualitative Inquiry. Volume 12 Number 2 April 2006.

[39] L. B. Henriksen, "How to Tell the Story? On Story and Narrative in the Research Process – A pragmatic constructive approach", Journal of Pragmatic Constructivism. Vol. 11. No 1., 2021, https://doi.org/10.7146/jopracon.v11i1.127250