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Yves JEANRENAUD
Ludwig-Maximilians-Universität Munich, Germany, yves.jeanrenaud@lmu.de

Anna-Kathrin WIMMER
Ludwig-Maximilians-Universität Munich, Germany, anna.wimmer@soziologie.uni-muenchen.de

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Digitalisation as an Opportunity for Women in STEM: Researching the Nexus of School, University and Labour Market

Y. Jeanrenaud [1]
Ludwig-Maximilians-Universität München (LMU Munich)
Munich, Germany
ORCID: 0000-0002-8378-2831

A.-K. Wimmer
Ludwig-Maximilians-Universität München (LMU Munich)
Munich, Germany
ORCID: 0009-0004-2150-1231

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ABSTRACT

In Germany, women are still dramatically underrepresented in the fields of STEM, especially in engineering: less than 25 percent of engineering students are female. Correspondingly underrepresented are women in engineering positions, too. Research has shown that diversity in the work force is crucial to develop successful solutions for a complex and sustainability-oriented world.

Therefore, our ongoing research project (01FP22M01), funded by the Federal Ministry of Education and Research (BMBF), focusses on the underrepresentation of

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[1] *Corresponding Author*
Y Jeanrenaud
yves.jeanrenaud@lmu.de

women in STEM, especially in mechanical and plant engineering. Using mixed methods of qualitative interviews and quantitative online surveys with female pupils, students and employees, as well as industry representatives, to create a comprehensive and multi-perspective picture of the conditions of engineering education and jobs. Thus, we can show what enables or hinders the recruitment, networking and initiative of women in engineering.

This practice paper therefore highlights the environment of engineering education and professional formation along the life course and the application of educational concepts in the light of digitalisation. However, because the research project is currently at the stage of implementing the survey and interviews, first empirical results are not yet available. Therefore, this paper will present the research project's background, the methodological approach and nonetheless focus on digitalisation and conceputalises how to shed light on the use of digital technologies in engineering education and professional development throughout careers.

1 INTRODUCTION

1.1 Underrepresentation of Women in STEM

The proportion of women[2] in STEM[3] subjects, particularly engineering and computer science courses that are central to mechanical and plant engineering[4], remains low and is rising only slowly (Statistik der Bundesagentur für Arbeit 2019; Jeanrenaud 2020, 8–23; Destatis 2021a). At the same time, mechanical and plant engineering is a key industry for Germany in which enormous disruptions due to advancing digitalisation processes (cf. Kagermann et al. 2013) can be observed and are still expected (cf. TCS 2017). This is why these subject groups electrical engineering/information technology, computer science and mechanical engineering/process engineering are of particular interest.

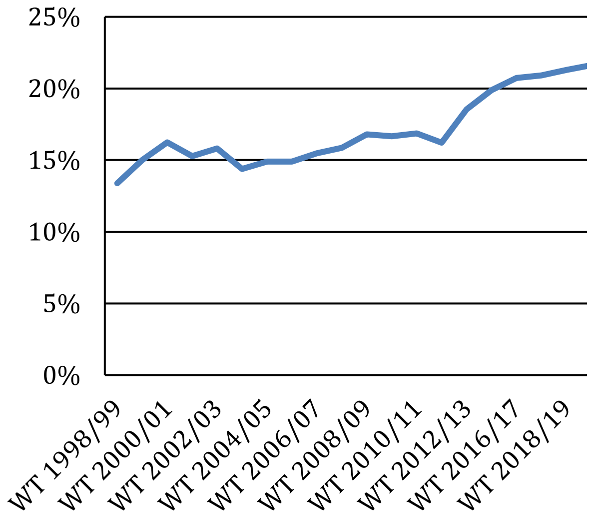

Fig. 1. Women's Proportion Among Female First-Year Students for Mechanical and Plant Engineering[4]

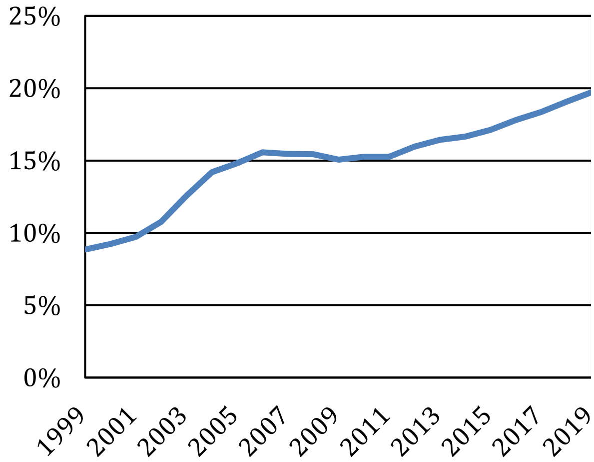

Fig. 2. Women's Share of Successfully Passed University Examinations for Mechanical and Plant Engineering[4]

While the proportion of women in the first semester of the subjects in question (Fig. 1) has risen from 13.39 percent in the 1998/99 winter term to 21.62 percent in the 2019/20 winter term (Destatis 2021a), there has also been an increase in the proportion of women passing university examinations in these subjects (Fig. 2) from

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[2] Even though gender is not exclusively thought of in binary terms on a theoretical and empirical level, but rather takes on ambivalent self-attribution and attribution to others as a structuring social category. Women are spoken of here in order to make this category tangible in terms of social and labour market policy. Thus, when we speak here of gender categories such as women and men, we are referring to persons in empirical data as well as theoretical considerations who define themselves as such (situationally and performatively, temporarily if necessary) (cf. Bereswill 2014).

[3] STEM is understood as abrvearion for the subects of Science, Technology, Engineering and Mathematics

[4] Following (Thomsen, Schasse, and Gulden 2020), these are the five subject groups in the subject classification of the German Federal Statistical Office (2020): Engineering, general (61), mechanical engineering/process engineering (63), electrical engineering/information technology (64), transport engineering/nautical engineering (65) and computer science (71). All together this group contains 46 subjects.

8.8 percent in 1999 to 19.73 percent in 2019 (Destatis 2021b). But women engineers in mechanical and plant engineering continue to be underrepresented even compared to STEM subjects as a whole, which have more than 26 percent of first-year students and STEM degrees in women's hands at more than 31 percent (Jeanrenaud 2020, 8–12).

However, a significant dropout of female graduates into other occupations and inactivity can be assumed, as Thomsen et al. (2020, 20) showed: only 18.5 percent of female graduates were found in a core occupation of production and manufacturing about twelve to 18 months after their engineering degree. This is despite lower dropout rates than men (Thomsen, Schasse, and Gulden 2020, 13; Destatis 2021b).

This in turn means that women are still not participating to the same extent as men in the shaping, employment and acquisition prospects and the growth in importance of digitalisation in mechanical and plant engineering, which is not only problematic from an equality perspective, but is also becoming increasingly difficult for Germany as a business location with regard to the specific STEM skills shortage (cf. BDA 2020). Because STEM professions in general, and especially core professions in mechanical and plant engineering, are of particular importance in the course of the accelerated digitalisation of many areas of society – industry, work, education, social life (cf. Frielingsdorf 2019). Such are STEM studies themselves (cf. Anger, Koppel, and Plünnecke 2016), it is particularly worthwhile to take a closer look at women's choice of field of study and career entry explicitly against the backdrop of trends and changes with disruptive potential for the mechanical and plant engineering industry as a core STEM sector (cf. Orendi 2019) in terms of an analytical looking glass.

Because it can be assumed that the underrepresentation of female engineers in mechanical and plant engineering is due to both cultural and structural causes (Jeanrenaud 2020, 22–30), the research methodologically lends itself both to a look at individual career and life trajectories and to linking these to social and organisational contexts. Therefore, the basic principles and framework conditions are to be analysed with regard to the sustainable recruitment of women for STEM professions in research and innovation.

1.2 Project's Goals

The aim of the project is therefore to develop recommendations for action for industry, science and politics in order to be able to react in an empirically sound manner to the underrepresentation of women in STEM fields (cf. Jeanrenaud 2020) and to identify which support services, especially for SMEs as well as schools and universities, could be specifically designed for this purpose. In this way, a cultural change should be initiated and promoted in the long term, which will bring more female STEM graduates into industrial companies and anchor them there in the long term, also taking into account the diversity of the special life situations of women.

Therefore, not only the active study choice orientation of female pupils should be reflected, but also the choice of female STEM students should be surveyed and analysed retrospectively. Furthermore, the question of factors in the course of STEM studies and in the transition to professional life is also in the focus of the project. Therefore, female STEM graduates are to be considered. This enables systematic access to the framework conditions in STEM professions and study course selection processes, which can be used to analyse the factors for successful recruitment, networking and successful anchoring of women in mechanical and plant engineering as an exemplary STEM core industry.

To this end, the following questions will be examined:

1. Where is the drop-out: why do below-average numbers of female graduates from engineering core subjects and computer science find their way into mechanical and plant engineering? At what point in the pathway and how do they get lost?
2. How do women engineers decide on specific courses of study, different companies and industries in the age of advancing digitalisation?
3. In this context, it is particularly interesting to see what role the design of the recruiting process plays (from university and company presentations to job advertisements and on-boarding, etc.).
4. What opportunities do digitalisation and other disruptive topics (e.g. new work, cf.Tarnoff and Weigel 2020) present for the mechanical and plant engineering industry (Orendi 2019) to attract more women engineers?
5. What is the role of (company) training in the course of talent retention and management? Studies (cf.Ebner and Ehlert 2018) indicate that, contrary to common assumptions, these have the potential to reduce churn and thus create individual career stability.

In order to be able to comprehensively research these questions, a mixed-method approach of qualitative and quantitative empirical methodology is particularly suitable (cf.Helfrich, Bollier, and Heinrich-Böll-Stiftung 2015; Johnson, Onwuegbuzie, and Turner 2014; Burch and Heinrich 2015). Further specific questions and sub-dimensions will probably be differentiated in the concrete preparation and in the course of the study.

Therefore, vectors and approaches for measures and projects to increase the proportion of women in STEM fields of particular importance for future-oriented and demand-oriented research and innovation, namely electrical engineering/information technology, computer science and mechanical engineering/process engineering, will be identified and condensed on a theoretical and empirical basis. These are based on the current state of causal research and suitably tailored empirical studies. Subsequently, appropriate measures as well as needs for action and, if necessary, further research, will be identified, which equally take into account the diversity of women's life situations, can be used multidimensionally and are correspondingly promising.

2 METHODOLOGY

2.1 Empirical Concept

Based on the goals and questions of the project, it is necessary to focus the study on empirical research into the transitions from school to university and from university to work and the change of jobs and/or companies in the course of life. The primary objective is to investigate the decision-making processes that speak in favour of or against a particular job in mechanical and plant engineering for female engineers.

Since cultural and structural reasons for this are the focus of the research interest, their effects on individual occupational and career paths will be ascertained by means of qualitative, problem-centred guided interviews (cf. Kurz et al. 2009; Witzel 2000; Meuser and Nagel 2009, 2018) with female students and engineers. Digitalisation should always be included as a cross-cutting theme and the question should be linked to it of what it changes in relation to (professional) decisions, careers, fields of activity and opportunities for female engineers. Furthermore, the attractiveness, opportunities and limitations of new work and working time models for female engineers (cf.Pugh 2017), which are further promoted by advancing digitalisation, should be addressed and evaluated in the interview. At the same time, the perspective of the companies should not be neglected, which is why a survey using a standardised online questionnaire of people in management positions from industry is also planned.

The interviews take place by (video) telephone with five cohorts of approximately ten persons each who are pursuing or have completed a university degree in a STEM subject relevant to mechanical and plant engineering and with a particularly low proportion of women.

The five cohorts of female engineers (I to V) are oriented to the time of the beginning of the study and, like the contact persons of the companies (VI), are recruited via a snowball system of various actors in the field (Schnell, Hill, and Esser 2018, 249) (associations, universities, female engineers/networks, etc.). In order to obtain a representative picture of the mechanical and plant engineering industry in Germany, approximately 380 responses from the approx. 21’600 companies nationwide (VdVC 2021) should be sought for a simple stratified random sample ($e = 5.0, z = 1{,}96$).

In order to obtain a picture of STEM women that is as diverse as possible, attention is paid to geographical, subject-related and biographical aspects (migration, proximity to education of the parental home, etc.).

2.2 Interview Cohorts

Empirical cohorts for the interviews are planned in five cohorts (I to V):

I. Schoolgirls in the process of choosing a course of study (approx. 17 years old)
   The main focus here is on study orientation motives, role models, the influence of gender roles and stereotypes.

II. Female STEM students (first / second semester)
Finding one's way in the degree programme, dropout and transfer issues as well as academic success are central to these interviews.

III. Advanced female STEM students (fifth / sixth semester)
These interviews focus on academic success, career planning and shaping one's life.

IV. Female STEM graduates (approximately one year after graduation)
Here, experiences of the transition from study to work, finding a job, aspirations and ambitions, life planning and the associated impressions are still very fresh and therefore the focus of research interest.

V. Young professionals
Approximately three years after STEM graduation. There are good opportunities for job mobility here, as 50 percent of male and female engineers are likely to have changed jobs for the first time after about 24 months, women even more often than men (Ambrasat et al. 2011). The women here are on average still under 30 years old and in the "rush hour of life" (BMFSFJ 2012). The issue researched here is the sustainable anchoring in the STEM profession.

Furthermore, the project deems it necessary to include the companies' perspective within the fields of mechanical engineering and plant engineering.

VI. Company perspective.
For this purpose, contact persons in management positions from companies will be interviewed in order to ascertain their perspective on the questions and topics as well as on the basis of the first interim results arising from the interviews of groups I to V. The interviews will be conducted in the form of a questionnaire. In this context, importance is attached to differentiating between different regions (e.g. east/west, rural/urban environment), company size (international groups/SMEs, family businesses and various central branches of mechanical and plant engineering, which is significantly facilitated by the quantitative survey.

This compilation of data creates the most diverse empirical perspective possible within the constraints of a project's duration of 36 months on the choice of study and the career entry and retention of women in mechanical and plant engineering, as well as on the diverse effects of changes in the world of work.

The interviews are each designed to last between 60 and 120 minutes. This time span allows for an in-depth empirical examination of the complex topics of the study. At the same time, it is reasonably easy for the participants to fit into their daily routine. A total of approximately 50 interviews will then be transcribed and analysed using the method of Qualitative Content Analysis (QIA) (cf.Schreier et al. 2019; Schreier 2014) according to Philipp Mayring (cf. 2016) / Udo Kuckartz (cf. 2016). The analysis software MAXQDA[5] is used for this purpose (cf. Steinke 2007). The open source software Limesurvey[6] is used for the online survey of companies in the mechanical and plant engineering sector.

3 DIGITALISATION AS INTERVENTION

In order to shed light on the environment of digital and traditional engineering education along the life course as well as the application of digital educational concepts and practices, it is necessary to reflect on if and how digitalisation can be understood as a way to improve the participation of women in STEM. Therefore, the project aims to conceptualise digital practices in terms of tools (e.g. Zoom, MS Teams, Cisco WebEx etc.) and learning contents (e.g. open education resources – OER, acquisition of skills to use the digital tools etc.) as an intervention into pedagogical contexts. For the project's point of view, it is necessary to highlight learning in the digital context in higher education institutions as well as on the job.

The extent to which these digital practices and learning contents can be understood as a critical intervention, as a short-term external influence on autopoetic systems that can mitigate or redirect exclusions and repulsive effects for women in STEM, must be explored further. This is ought to shed light on the question of how digital practices enable more diverse lifestyles in STEM professions, too.

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[5] www.maxqda.de

[6] https://community.limesurvey.org/

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