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# Motives for Choosing an Area of Expertise in Chemistry: Recommendations for Higher Education

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## Abstract

*The choice of an area of expertise (for example inorganic chemistry) in higher education in Germany sets the first milestone in individual profile development and plays a key role for the qualification work of the respective degrees (B.Sc., M.Sc. and Ph.D.). Hence, the various influencing factors concerning the choice of an area of expertise should be clearly described in order to educate highly motivated junior chemists. The identification of these factors may unveil potential parameters for the optimization of university education. In addition, gender-specific factors may be unmasked and used for gender-sensitive education. The motivational effects for choosing an area of expertise for chemistry students have been qualitatively examined in a previous study. As a result, external as well as internal factors influencing the choice were deduced, implying a possible gender-specificity. The here presented complementary quantitative investigation examines the importance as well as the motivational effects of the individual factors, additionally considering possible gender differences. We can show that individual motives (e.g. research interest, work environment) can be (very) motivating factors regarding the choice of expertise. Furthermore, gender-specific influencing factors for the explicit motivation regarding the choice of an area of expertise of women were identified, i.a. the motivating effect of informational events. Moreover, based on the preference for interdisciplinary researches a gender difference can be deduced. As a result, recommendations for the optimization of higher education can be derived, providing a contribution to gender-sensitive education.*

**Keywords:** *Choice, Area of Expertise, Recommendation, Higher Education*

## 1. Introduction

Economic structural change in the 21st century is expected to increase demand for graduates, especially in STEM disciplines. One reason are rapidly advancing technologies, making it necessary to increase scientific research in the face of economic and societal challenges. Furthermore, the preservation and further development of the German industry's added value can only be guaranteed if appropriate STEM specialists are able to meet the requirements of modern innovation. It is also important to take demographic change into account, so that a sufficient number of qualified graduates are available to the labor market [1]. The universities as educational institutions play a significant role in the training of specialists. In particular, the preparation of qualification work lays the foundation for individual profiling up to specialization. In order to be able to train and ensure a highly motivated upcoming generation in the field of chemistry, the relevant factors (defined after Stuckey et. al, 2013, p. 19) and their motivational effects regarding the choice of an area of expertise (further referred to as: CAE) should be derived quantitatively [2].

## 2. Research Questions

The research questions were derived from a previous study (see [3]). In this exploratory study, a complex construct with seven causative external and internal factors was developed [3].

> *„The systematic deduction showed that the sub-categories university education, research interest, subjective level of difficulty and the work environment are central motives in the choice of an area of expertise. Additionally, the working methods and role models were mentioned frequently. Furthermore, female respondents also mentioned formal formats (e.g. informational events, mentoring programs) as important orientation aids." (cf. Milsch, 2017, S. 573)*

Accordingly, for this complementary quantitative study these underlying questions follow:

1. What are the most relevant sub-categories in the CAE?
2. Which are the most motivating factors in the CAE?

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3. Which recommended actions can be derived from the results of the first two research questions?
4. Are there any gender differences in the relevance and motivational effect of the individual factors?
5. Are there specific research areas that are more strongly prioritized by one gender?

Based on these questions, potential parameters for university teaching ought to be derived, in order to maintain the motivation, especially in students, and thus ensure a highly motivated upcoming-generation.

## 3. Research Methodology

### 3.1 Instrument

A paper and pencil study was conducted for the survey. The first section of the questionnaire consisted of 18 questions, with four-tier response scales and the following options: very motivated, motivated, demotivated, very demotivated. In this case, a scale center was consciously dispensed in order to prevent a so-called "escape category" [4]. Alternatively, the option "unimportant factor" or "not reasonably answerable" was given in order for respondents to clearly distinguish between important and unimportant factors. Furthermore, for the consideration of possible gender disparities, a question was added concerning 'compatibility of family and career'. In the second part, explicit interest in the researches was investigated. For this purpose, 35 research fields in chemistry were presented, reflecting classic chemistry and interdisciplinary contexts (multiple answers were possible).

### 3.2 Participants

142 chemistry students (B.Sc., M.Sc. and Ph.D.) from the Georg-August-University Göttingen were asked, thus representing a partial survey. The exact composition can be found in Table 1.

Table 1: Listing of the participants with their respective degrees and gender distribution

| | Number (N) | Percentage Distribution | Gender Distribution | | |
|---|---|---|---|---|---|
| | | | Male | Female | Not Mention |
| B.Sc. Students | 36 | 25.4% | 21 (58.3%) | 15 (41.7%) | 0 |
| M.Sc. Students | 31 | 21.8% | 25 (80.6%) | 6 (19.4%) | 0 |
| Ph.D. Students | 75 | 52.8% | 58 (77.3%) | 15 (20.0%) | 2 (2.7%) |
| Total | 142 | 100% | 104 (73.2%) | 36 (25.4%) | 2 (1.4%) |

### 3.3 Data Analysis

The collected data was evaluated with the statistics program *SPSS*. In addition to the consideration of frequency tables and the mean values, the t-test or, if necessary, the chi-square test with respect to a gender difference was applied to the individual items. If a significant difference occurred in the t-test, the correlation coefficient (r) was additionally calculated.

## 4. Results and Discussion: Recommendations for the University

The results (see Table 2) are examined in the initial subcategories from Milsch, 2017 [3]. It is striking that six out of the seven subcategories were rated by nearly 80% of the students as important for the CAE. Solely the formal formats were considered by only about 56% of students as an important factor.

Table 2: Listing of the relevance of the subcategories

| | N (Relevance) | N (Irrelevance) | N (Not Mention) |
|---|---|---|---|
| University Education | 135 | 2 | 5 |
| Working Method | 133 | 4 | 5 |
| Research Interest | 132 | 4 | 6 |
| Role Models | 130 | 6 | 6 |
| Work Environment | 129 | 6 | 7 |
| Subjective Level of Difficulty | 113 | 21 | 8 |
| Formal Formats | 76 | 45 | 21 |

It becomes clear that the subcategories are almost equally strongly weighed. Therefore, in the further evaluation of the results, only the individual associated items of the subcategories should be considered in order to be able to make differentiated statements (see Table 3).
The presented quantitative study shows that many different factors are considered as relevant in the CAE (see Table 3). All factors show a motivating character. Above all, the department internships as well as the experienced working atmospheres show the highest motivational values. Hence, universities should grant more opportunities for departmental internships and should foster positive working atmospheres (for example, team-building measures). Additionally, the accounts from third parties about a department are relevant, because of which the systematic promotion of the working environment, in perspective, has an outwardly-acting synergetic effect. Furthermore, students are shaped and motivated by role models from their day-to-day studies. In addition, care should be taken to address the individual research interest. The data shows that only certain disciplines are considered relevant in the choice of interest, which makes them more relevant. To increase the interest for other disciplines, the lectures, in particular, could be used to complementarily increase the motivation.
The subjective level of difficulty is similarly significant as the research interest, since only individual levels of difficulty are considered in the choice. However, caution should generally be exercised, as this may be seen as more demotivating. Also practical work in bigger laboratories with lots of students (hall internships) as well as theoretical work should be designed more motivating, for instance by integrating different teaching methods. In addition, universities should offer more formal formats, since particularly female chemistry students can be effectively supported in their CAE.

Table 3: Subcategories with their respective items in terms of relevance and motivation

| | | N (Relevance) | M (Motivation) | SD (Motivation) |
|---|---|---|---|---|
| ***University Education*** | Lectures | 129 | 1.84 | 0.635 |
| | Hall Internships | 120 | 2.12 | 0.822 |
| | Departmental Internships | 95 | 1.48 | 0.634 |
| ***Working Method*** | Practical Work | 123 | 1.78 | 0.608 |
| | Theoretical Work | 118 | 2.19 | 0.495 |
| ***Research Interest*** | Interest Inorganic Chemistry | 81 | 1.94 | 0.827 |
| | Interest Organic Chemistry | 89 | 2.09 | 0.848 |
| | Interest Physical Chemistry | 97 | 1.92 | 0.886 |
| ***Role Models*** | Fellow Students | 85 | 1.94 | 0.472 |
| | Family Members | 33 | 1.88 | 0.485 |
| | Professors | 114 | 1.93 | 0.527 |
| ***Work Environment*** | Third Party Reports on Work Environment | 92 | 1.68 | 0.694 |
| | Oneself Experienced Work Environment | 116 | 1.55 | 0.690 |
| ***Subjective Level of Difficulty*** | Subjective Level of Difficulty in Inorganic Chemistry | 61 | 2.18 | 0.646 |
| | Subjective Level of Difficulty in Organic Chemistry | 72 | 2.28 | 0.809 |
| | Subjective Level of Difficulty in Physical Chemistry | 86 | 2.10 | 0.958 |
| ***Formal Formats*** | Informational Events | 43 | 1.88 | 0.544 |
| | Lecture Series „Beer & Pretzel“ | 57 | 1.74 | 0.518 |

## 5. Results and Discussion: Gender Differences

No gender differences (N = 140, 25.7% female, 74.3% male) were observed considering the relevance of individual factors. Gender disparities were only determined in motivation. The t-test shows that there is a very significant difference in the 'informational events' ($p$ = 0.008, r = 0.53) and a significant difference in 'compatibility of family and career' ($p$ = 0.013, r = 0, 39) compared by sex.

Table 4: Gender comparison of the items 'Informational events' and 'compatibility of family and career'

| | Female Chemistry Students | | | Male Chemistry Students | | |
|---|---|---|---|---|---|---|
| | N | M (Motivation) | SD (Motivation) | N | M (Motivation) | SD (Motivation) |
| Informational Events | 13 | 1.54 | 0.519 | 30 | 2.03 | 0.490 |
| Compatibility of Family and Career | 9 | 3.22 | 0.667 | 31 | 2.52 | 0.724 |

As a result, it can be concluded that female chemistry students are more motivated by informational events than male chemistry students. In addition, female chemists are more demotivated by the compatibility of family and career in the CAE than their male fellows (see Table 4).
Furthermore, individual fields of chemistry were tested for a gender difference, showing that only three interdisciplinary researches indicated a correlation. 'Chemical biology' presents a highly significant correlation ($p = 0.000$) whereas 'biochemistry' ($p = 0.002$) and 'computational chemistry' ($p = 0.002$) show very significant correlations.

Table 5: Gender distribution of researches with significant gender disparities

| | N (Female Chemistry Students) | N (Male Chemistry Students) |
|---|---|---|
| Biochemistry | 15 (46.9%) | 17 (53.1%) |
| Chemical Biology | 13 (65.0%) | 7 (35.0%) |
| Computational Chemistry | 0 (0.0%) | 23 (100.0%) |

In conclusion, female chemistry students show a stronger interest in the research of 'chemical biology' and 'biochemistry' than male chemistry students. In turn, male chemistry students show a greater interest in 'computational chemistry' than female chemists (see Table 5). In order to increase the women's quota in certain researches, it should be considered that qualification work is offered in a biological context. Women may feel more responsive and cover issues that they previously considered unattractive.
Finally, a comparison can be made on the basis of the exploratory study [3]. The preliminary study found indications for gender difference in the 'formal formats', 'role models' and in the interdisciplinary nature of the 'research interest'. These assumptions can only be supported in part. Only in the related item 'informational events' of the subcategory 'formal formats' a gender difference was identified. For the individual items of the subcategory 'role models', no gender differences were found. However, the data supports the hypothesis that gender differences can be found in interdisciplinary topics of research interest.

## 6. Consideration

The collected data offers first indicators for an optimization of the university teaching. However, it must be further examined to what extent the results can be extrapolated for (inter)national comparisons. Above all, the students' interest at other universities may vary due to different academic environments.

## References

[1] Hetze, P. “Nachhaltige Hochschulstrategien für mehr MINT-Absolventen,” Essen, 2011.
[2] Stuckey, M., Hofstein, A., Mamlok-Naaman, R. and Eilks, I. “The meaning of ‘relevance’ in science education and its implications for the science curriculum,” Stud. Sci. Educ., vol. 49, no. 1, 2013, pp. 1–34.
[3] Milsch, N. “Motives for Choosing an Area of Expertise in Chemistry: An Explorative Study at University Level,” in New Perspective for Science Education, Florenz, 2017, pp. 570–575.
[4] Faulbaum, F., Prüfer, P. and Rexroth, M. "Was ist eine gute Frage?: Die systematische Evaluation der Fragenqualität" Wiesbaden, VS Verlag für Sozialwissenschaften, 2009.