INTEGRATING ENTREPRENEURIAL EDUCATION TO IMPROVE FOUNDATION READINESS OF CHEMISTRY STUDENTS IN GERMANY AND POLAND: A PDCA PERSPECTIVE

Sebastian Walther, Fresenius University of Applied Sciences Germany
Haubold Stephan, Fresenius University of Applied Sciences Germany
Renata Dobrucka, Poznań University of Economics and Business Poland

ABSTRACT

Chempreneurs are founders from the faculty of chemistry. Their task is to turn ideas into innovative products and processes. The aim is to find solutions to current challenges that need to be marketed to a broad audience outside the classroom. The realisation of innovative ideas with social relevance can generate income, create jobs and promote the economy in general. A German chemistry student is 54% less likely to start a business than the average German student. Previous studies have shown possible effects of gender, culture, social capital, subjective norms, motives and barriers for chemistry students in Germany. In addition, the effect of Entrepreneurship Education (EE) on chemistry students in Germany has already been analysed. With the surveys conducted (one comparative in Germany and Poland and two in Germany before and after EE), the aim is to propose a methodology for the long-term and continuous improvement of entrepreneurial intention, for which we have made cross-comparisons between the surveys. Finally, we propose a pedagogy for the introduction/expansion of entrepreneurship in chemistry and discuss approaches for future research.

Keywords: Graduate Education/Research, Chemistry, Entrepreneurship, Entrepreneurship Education, Germany.

INTRODUCTION

The concept of chemical entrepreneurship refers to the commercial application of innovations in chemistry to the market or to potential buyers (Oyeku et al., 2015). Innovations, defined as new processes, products or procedures that combine ideas, inventions and dissemination,, can be realised through technology transfer in the form of patents, university spin-offs or foundations (Wolf et al., 2022). The application of chemical innovations is crucial for global challenges such as health, plant production, energy conversion, water resources, climate change and others. In Germany, the chemical industry contributes 6.7% to GDP and ranks third in the world behind the USA and China (Federal Ministry of Economics and Climate Protection,

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2023; Statista, 2023; Rudnicka, 2023). The combination of science and entrepreneurship is therefore crucial for the continued existence of the chemical industry (Sachse & Martinez, 2016). Academic research can be commercialised through patenting, licensing or company formation, but requires marketable products from research (Oyeku et al., 2015; Phan & Siegel, 2006). For example, BioNTech SE, a company that developed Covid vaccines, was founded by German innovators in 2008 (Federal Ministry of Education and Research, 2020). Not all scientists are aiming for commercial goals (Parker et al., 2018). Chemistry education often emphasises the scientific aspects but neglects their societal relevance and translation into marketable products (Nwakaego & Kabiru, 2015; Oyeku et al., 2015). Three surveys were conducted, including a cross-country comparative study in Germany and Poland, which included several analyses such as cross-country comparisons, gender comparisons, comparisons by gender and immigration, and social capital. Furthermore the effect size based on ordinal regressions was also implemented. In addition, a study to evaluate the impact of entrepreneurship education in Germany were generated, in which two surveys were conducted - one before and one after the entrepreneurship education lessons. Given the complexity and constant change in the field of chemical entrepreneurship, the use of quality management and quality assurance tools is essential. The Plan-Do-Check-Act cycle provides a structured method for continuous improvement and innovation, which is particularly relevant to bridge the gap between academic research and entrepreneurship. Against this background, previous research has provided important insights into the factors influencing chemistry students in Germany and Poland. This study builds on these findings and examines the impact of entrepreneurship education on chemistry students in Germany, using the Plan-Do-Check-Act cycle as a guide for the continuous improvement and implementation of innovative ideas. The following is an explanation of entrepreneurship education in general, its importance, benefits and application.

Entrepreneurship Education

Definition and goal for entrepreneurship education

Entrepreneurship Education (EE) is defined as educational programmes that aim to promote entrepreneurial thinking, skills and behaviours in learners (Kuratko, 2005). Depending on the source, the focus of the definition can vary between developing entrepreneurial types (Fayolle & Gailly, 2015) or, for example, entrepreneurial competences (Kuratko, 2005). EE is usually implemented at schools, universities and other educational institutions. The definition of EE can be traced back to different models and views. The main objectives of EE can be described as the following aspects:

1. The promotion of entrepreneurial thinking and action
2. To impart knowledge about foundation processes and risks
3. Strengthening learners' willingness to take risks and their self-confidence
4. Developing strategic planning and problem-solving skills

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5. Promoting creativity and innovation skills

Important theories of Entrepreneurship Education

The theory of planned behaviour is one of the central theories in the field of EE (Ajzen I., 1991). This theory postulates that the intention to perform an entrepreneurial behaviour is influenced by the individual's attitude towards this behaviour, the subjective norm (social expectations regarding the behaviour) and the perceived behavioural control. The basic model includes the attitude, the subjective norm and the perceived behavioural control of the agent. The corresponding aggregates and behavioural beliefs are a positive or negative attitude towards the behaviour. The effects of the attitude towards a behaviour and the subjective norm on the intention are moderated by the perception of behavioural control. In general, the more favourable the attitude and subjective norm and the greater the perceived control, the stronger the person's control over their intention to perform the behaviour in question should be (Ajzen I., 2006). At the same time, this model is the most frequently cited and therefore most widely accepted model (Walther et al., 2023).

Another model is the entrepreneurial mindset, which describes a certain way of thinking that is crucial for successful businesses (McGrath, 2000). It includes characteristics such as a willingness to take risks, flexibility, a willingness to innovate and the ability to seize opportunities. The promotion of this mindset is a central concern of entrepreneurship education and can have a direct influence on students' willingness to start a business.

Entrepreneurial self-efficacy can be described as a further model in which a person is convinced that they are capable of mastering entrepreneurial tasks and being successful if they are convinced of this (Boyd & Vozikis, 1994). This approach is based on self-efficacy theory and emphasises the importance of self-confidence and beliefs in relation to the performance of entrepreneurial actions (Bandura, 1977).

Models of Entrepreneurship Education

There are various models for EE with different processes and procedures. For example, the Entrepreneurial Event Theory postulates the intention to start a business as a reaction to specific events or situations (Shapero & Sokol, 1982). This model describes how individual experiences, e.g. education, work environment and personal events, influence the willingness to start a business. The phase model divides EE into pre-action and post-phases (Kyrö, 2005). During the pre-action phase, students are prepared to deal with entrepreneurial aspects, while the action phase focusses on practical activities. In the post-phase, students reflect on their experiences. This model is relevant for the design of entrepreneurship education as it structures the learning process in different phases and offers a holistic approach to the development of entrepreneurial skills. Another approach is the Experiential Learning Model. This model emphasises experiential learning and the importance of practical experience in teaching and learning processes. Through

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the cycle of concrete experiences, observation and reflection, abstract conceptualisation and active experimentation, students internalise entrepreneurial skills and behaviours (Kolb, 1984). The importance of practice-based teaching methods in entrepreneurship education was emphasised, particularly with regard to the development of entrepreneurial skills in students.

Scientific studies on methods and effectiveness

Previous studies are inconsistent and contradict each other on the question of whether entrepreneurship can be promoted through education. While some studies report positive effects of entrepreneurship education on entrepreneurial intentions (Block et al., 2013; Souitaris et al., 2007; Walter & Dohse, 2012), other studies indicate that the effect is statistically irrelevant or even negative (Oosterbeek et al., 2010; Lorz, 2011; Graevenitz et al., 2010). In a comprehensive meta-analysis, significant effects of entrepreneurship education on the development of entrepreneurial skills and attitudes towards starting a business were demonstrated (Bae et al., 2014). In addition, studies on the long-term effects of entrepreneurship education on actual foundation activity should be considered to obtain a comprehensive picture of the effectiveness of educational programmes.

In addition to the mode of action, the implementation of entrepreneurship education also varies. It is argued that entrepreneurship education is either a method or a process (Neck & Greene, 2011; Welsh et al., 2016). The path to student entrepreneurship is described as a journey and sequence of events or a series of opportunities or steps (Steinberg, 2005). In contrasting method and practice, it is argued that EE is a method with a series of practices that juxtapose phases of learning with steps to be completed, as opposed to a process with known inputs and predetermined outputs where the focus is on action rather than planning (Neck et al., 2014). Analysing the advantages and disadvantages of different teaching methods for EE is important for future implementations of these programmes. Research has shown that experiential learning, mentoring programmes, simulation games and hands-on projects can have a significant impact on the development of entrepreneurial competencies (Neck & Greene, 2011). In addition, the importance of interdisciplinary approaches and networking with the business world in relation to the effectiveness of entrepreneurship education, such as the approach of a cooperative innovation strategy, should be highlighted. The German Fresenius University of Applied Sciences has developed a cooperative innovation strategy called PANDA (Powerful Actions for the Natural Development of microAccelelorator) to inspire students to become entrepreneurs (Wolf, et al., 2020). Since 2017, this approach has been implemented in various countries with companies in Germany and Poland.

In addition, learning as an investment and learning for an expected or predictable return as well as cooperative learning and competition have been contrasted (Neck et al., 2014). In the classroom, students can be introduced to a culture of innovation through projects, proposals, product development, or research (Brown, et al., 2010; Donovan et al.,2014) for which students receive assessment or recognition (Abigail et al., 2022). The growth and progress of innovation in

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the classroom is hindered by several factors. For example, the opportunities and innovations for chemistry education are still unexplored due to weaknesses in outcome-based instruction (Turunen & Byers, 2012). Another problem may be the focus of academic institutions on publicising innovations that do not consider the needs and desires of society (Owen et al., 2013).

Continuous improvement through Plan-Do-Check-Act cycle

The Plan-Do-Check-Act cycle (PDCA), also known as Deming cycle (1993), was originally developed by Walter A. Shewhart in the 1920s and later described by W. Edwards Deming (Shewhart, 1931). This management method is used for the continuous improvement of processes and products. The process steps of the cycle include various actions, while the "*Plan*" process involves setting goals, developing plans and identifying resources, the "*Do*" step involves implementing the planned measures. During the "*Check*" process, the results are measured and compared with the targets in order to identify deviations. In the final Act step, steps to correct problems or further improve the process are defined in the action plan (Deming, 1982). The PDCA cycle is widely used in various areas such as quality management, process optimisation, project management and continuous improvement. In quality management, the PDCA cycle is frequently used to improve the quality of products and services and to solve quality problems (Juran, 1999). The PDCA cycle is used to enable a systematic and structured approach to problem solving and improvement by creating feedback loops and using lessons learnt from previous activities to inform future decisions. Through this iterative process, organisations can achieve continuous improvement and achieve goals more effectively (Moen, et al., 1991).

Based on the literature and the previous results, the following hypothesis was investigated: The integration of a PDCA cycle into an EE programme improves the methodology for the development and implementation of business ideas and enables students to continuously optimise their entrepreneurial projects and ultimately make them more successful.

METHODOLOGY

This study is a comparative analysis of three surveys of chemistry students on their willingness to start a business with various influencing factors. The first survey (Sep. 2022 – Jan. 2023) was comparative in Germany and Poland and the second and third surveys were conducted before (Nov. 2023) and after EE (Dec. 2023) in Germany, analysing innovation-oriented technology transfer from the students' perspective. The surveys were each based on identical questionnaires and were conducted online in order to generate as many participants as possible. A process overview of the research steps carried out can be found in Figure 1.

Figure 1

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CHRONOLOGICAL SEQUENCE OF THE RESEARCH STEPS CARRIED OUT

For reasons of time and cost, a longitudinal design was chosen for our study. The country This article contains the data and results of all surveys. The various sub-steps are therefore explained below.

Entrepreneurship Education

A cohort of students at Fresenius University of Applied Sciences was selected to investigate the effects of EE on chemistry students. This consisted of students in the 1 and 3 semester Bachelor of Chemistry programmes. The students were asked to participate in the first survey without any preparation or information. After the survey, EE was provided by an experienced charismatic founder at a low-threshold level, which is intended to establish the founder as a role model in order to increase the probability of founding a company (Walther, et al., 2024). The findings of the first survey (Sep. 2022 - Jan 2023) were used, such as low-threshold communication, the development of motives or the removal of barriers (Walther et al., 2023). The time gap between the surveys and the lectures was also intended to give the students the opportunity to exchange ideas with each other and possibly to process them in their private environment, which should increase the subjective norm (Walther et al., 2024). EE focussed on finding ideas, the process of founding a company and closing the company. The lessons were conducted by a chemist to maintain proximity to the students. Possible barriers such as a lack of business knowledge or foundation capital were addressed directly. The students had the opportunity to ask questions and clarify their own areas of focus at any time. The lecture was followed by a foundation game in groups, which served to find potential ideas for a foundation. The aim was to intensively analyse an idea and develop possible concepts. The second survey took place at the start of a new lecture and after a break of several days. Only after the second survey was completed was the purpose of the surveys and the aim of the research explained in order to rule out possible errors.

Questions

The questions for the questionnaires used come from various studies and are identical in each case (Walther, et al. 2024). The questions are divided into demographic factors in order to be able to make statements about different subgroups, the probability of starting a business or career intentions and the assumed influencing factors from the TBP with additional questions. After the demographic questions on gender, migration, nationality and age, participants were excluded on the basis of their student status in order to obtain the desired data. Subsequently, study-related characteristics such as place of study, subject, intended degree, total duration of study, type of employment or the presence of founders in the environment were recorded and questions were asked to determine the latent constructs. For this purpose, questions from various studies were used, which were adapted to a 6-point Likert scale to force the selection. Absolute ignorance (1) to comprehensive knowledge (6) for questions on basic knowledge, or I don't know (0), strongly disagree (1) to strongly agree (6) for the others. The likelihood of starting a business was surveyed

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using two different types of questions, firstly the likelihood of starting a business after graduation, which ranged from very unlikely (1) to very likely (6), and secondly career intentions with the options of public service, employment and starting a business. An overview of the question categories used, the number of questions, the presence of the "*I don't know*" response option and the question source can be found in Table 1.

Table 1
OVERVIEW OF APPLIED STUDY QUESTIONS WITH SOURCES, NUMBER AND ADDITIONS

Question Categories	number of questions	Answer option "I don't know"	Question source	Addition of own questions
Foundation knowledge	3	no	(Cook, Heath, & Thompson, 2000)	no
Perceived educational support (PES) & Perceived Support of the university (PSU)	10	yes	(Roy, Akhtar, & Das, 2017)	yes
subjective norm (SN)	2	no	(Saeed, Yousafzai, Yani-De-Soriano, & Muffatto, 2015)	no
Founding intention	2	no	(Saeed, Yousafzai, Yani-De-Soriano, & Muffatto, 2015)	no
Perceived Career options (WCO)	6	yes	(Cook, Heath, & Thompson, 2000)	no
Perceived Behavioural control (PBC)	9	yes	(Zapkau, Schwens, Steinmetz, & Kabst, 2015)	no
Self-assessment for the foundation (SF)	3	yes	(Krueger, Reilly, & Carsrud, 2000)	no
Motives for Starting a Business	17	yes	(Pruett, Shinnar, Toney, Llopis, & Fox, 2009), (Solesvik, 2013)	yes
Barriers to Starting a Business	19	yes	(Pruett, Shinnar, Toney, Llopis, & Fox, 2009), (Solesvik, 2013)	yes

Participants

A total of 4,367 people and 120 professors or student representatives were contacted for the 1st survey in Germany and Poland. In February 2023, we received fully completed questionnaires from 1,287 participants, which corresponds to a response rate of 29.4 % and can be considered acceptable compared to other web-based studies (Cook, Heath, & Thompson, 2000). Before conducting statistical analyses, 320 participants were conducted due to incomplete data. We also excluded participants who stated that they were not currently studying (n = 135), were in a different field of study (e.g., teaching or electrical engineering), or were studying in a different country (n = 21). The final sample therefore consisted of 811 students, 498 from Germany and 313

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from Poland. The average time spent in the questionnaire was 9.25 minutes. A summary of the final sample and its distribution is given in Table 2. Demographic composition 1. survey Germany and Poland.

Table 2
DEMOGRAPHIC DISTRIBUTION OF STUDY PARTICIPANTS IN THE 1ST SURVEY IN GERMANY AND POLAND

Factor	Germany	Poland
Age [years]	24.2 (SD = 3.42)	22.9 years (SD = 2.82)
Men	48.0 %	28.1 %
Women	50.6 %	70.0 %
Migration background	23.3 %	20.4 %
Foreign citizenship	15.5 %	3.8 %
Public university	79.9 %	100.0 %
Bachelor's programme	52.6 %	71.6 %
Master's programme	25.3 %	20.4 %
No income	36.7 %	59.7 %
Full-time employment	6.8 %	5.4 %
Social capital [yes]	41.0 %	38,4 %

The surveys with EE were conducted in Germany at the Fresenius University of Applied Sciences. The total group size for this course, consisting of the 1st and 3rd semesters, is 75 people. For the pre-course survey, 67 participants completed a questionnaire, which corresponds to a response rate of 89.3 %. In the second post-course survey, 51 participants completed their questionnaires in full and were able to analyse them, which corresponds to a response rate of 68.0%. For the statistical analyses, 3 participants before the course and 4 participants after the course were excluded due to incomplete data. Thus, the final sample consisted of 111 students, 64 before entrepreneurship education and 47 after entrepreneurship education. The average time taken to complete the questionnaire was 9.25 minutes. An overview of the distribution of the study participants can be found in Table 3.

Table 3
SUMMARY OF THE STUDY PARTICIPANTS

Factor	**Germany**	
Entrepreneurship Education	before	after
Age [years]	23.6 ± 3.1	23.7 ± 3.2
Men	45.3 %	46.8 %
Women	53.1 %	48.9 %
Migration background	18.9 %	14.8 %
Foreign citizenship	15.6 %	8.5 %
Bachelor's program	93.3 %	95.7 %
No income	37.5 %	34.0 %
Full-time employment	6.3 %	6.4 %
Social capital [yes]	48.4 %	48.9 %

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Statistical analysis

Statistical analysis was carried using IBM SPSS Statistics version 28.0.1. The data was tested for normal distribution using Shapiro-Wilk tests. Not all variables in the data set have a normal distribution and some variables have an ordinal scaling. The logistic ordinal model is used to study the effect of continuous and categorical variables on a dependent variable (Fisher & Yates, 1938; Reed & Wu, 2013).

Further processing is analogous to the study already conducted (Walther, et al., 2024). In the course of comparability, no new exploratory factor analysis (EFA) was carried out using the maximum likelihood extrusion method. In this way, 12 variable factors can be formed from 69 variables.

To create an ordinal logistic regression (OLR), the results are coded as Y = 1 or Y = 0, whereby the result either occurs (1) or does not occur (0). In addition, OLR is performed as an analysis of the factor variables. Thus, OLR is used to determine the effect size (Exp(B)) as a 95% Wald confidence interval, to predict effects, to detect trends and to predict the relationship between an endogenous variable at ordinal level and two or more categorical or continuous exogenous variables. The chi-square test and the goodness of fit according to Person and Deviance as well as the pseudo R-square according to Nagelkerke and Cox I Snell are specified as further parameters for the OLR. The second analysis method used was the Mann-Whitney-U-Test for independent samples, which is a non-parametric alternative to ANOVA, as the data were not completely normally distributed. The Kruskal-Wallis test compares the ranks of the data. The result of an ANOVA analysis is the standardised z-value, which indicates by how many standard deviations the test statistic deviates from the expected value, and the significance level (p-value), which is determined by the distribution function of the test.

The significance level was set at 5 %. The calculation of the probability of starting a business is based on the percentage of participants who chose starting a business as a career option. The results are presented in the form of a table containing the factor, the country, the number of "*I don't know*" statements, the percentage of "*I don't know*" statements, the sample size (n), the mean, the median, the Wald chi-square and the p-value (p).

RESULTS

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In the following, a method proposal for the implementation and evaluation of entrepreneurship education is suggested. The methodology and the results of previously conducted publications are used and combined in chronological order as a PDCA cycle methodology.

Plan – prepare the survey determine methodology

When planning the EE, research has shown that the TPB is currently the most accepted model (Walther, et al., 2023). For the application, the model was supplemented by the variable groups foundation knowledge, perceived support by the university / perceived educational support, motives and barriers. This resulted in the model as shown in Figure 2.

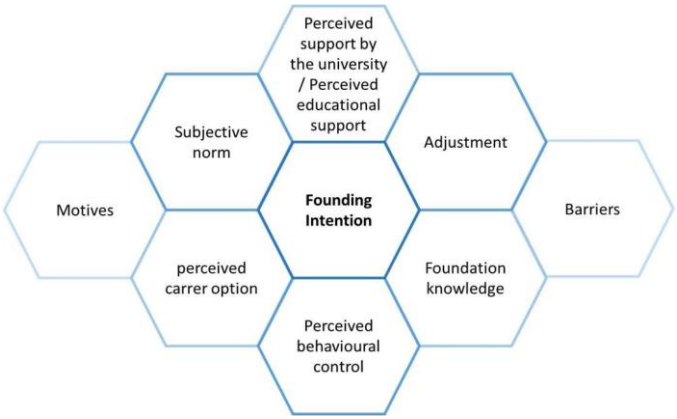

Figure 2
ADAPTED TPB

Furthermore, the number of theoretical foundations could be analysed by using the number of chemistry students, the TEA rate and the actual chemical foundations in the period 2016 - 2019. In relation to the actual foundations, this results in a potential for Germany of 54 % (Walther, Renata, & Haubold, 2023). In combination, these results led to the planning of an in-depth study of foundation behaviour among chemistry students in Germany, with Poland's chemistry students serving as a reference.

Do – conduct survey

The use of online surveys, for example, is recommended for the collection of participant data. Due to the wide distribution rate and the use of different languages, data can be collected simultaneously in several countries. The use of security questions, such as in this case asking for the place and status of study or degree programme, can ensure data quality and rule out false information. An example from the comparative survey of chemistry students from Germany and Poland is shown in Figure 3.

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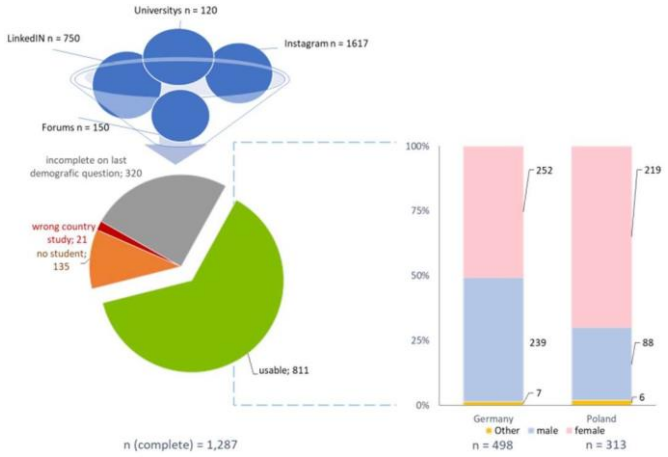

Figure 3.
SUMMARY OF DATA COLLECTION FROM COUNTRY COMPARISON SURVEY

Check – comparative survey GER and PL

When analysing the study results, the use of suitable forms of presentation is recommended. For example, the use of a box plot can provide an initial overview of the distribution of the data. As shown in Figure 4 as a comparison of the two countries analysed (Pietrzak & Paliszkiewicz., 2015).

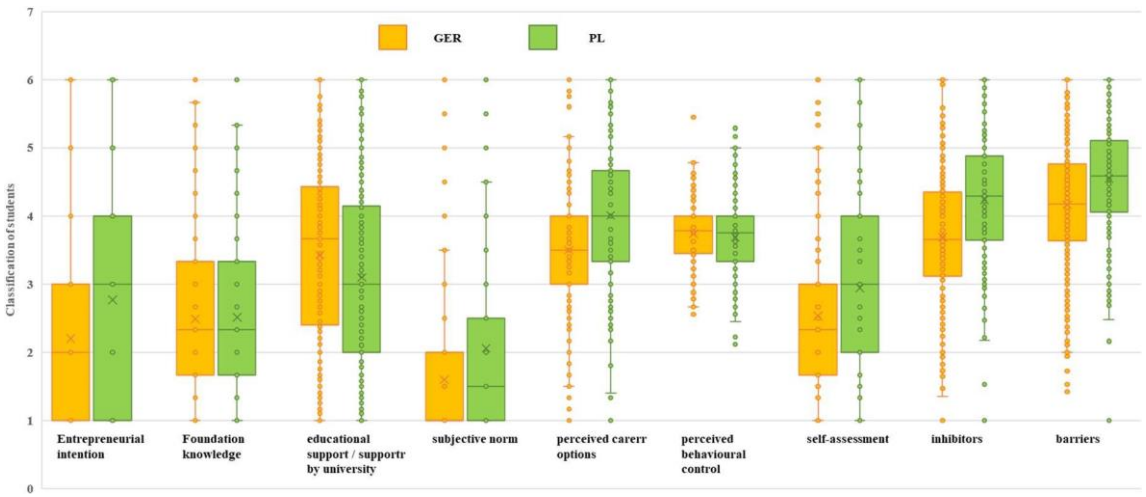

Figure 4.
BOXPLOT ALL RESULTS FAR FACTORS GER AND PL

The comparison of the different variable groups as mean values in the boxplot already shows differences in the location parameters in the countries which were confirmed by ANOVA (Walthe et al.2023). In addition to comparing the source countries, other demographic questions

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can also be used to form subgroups. Figure 5 shows the entrepreneurial integrations for all possible subgroups with more than 20 participants for the two countries analysed.

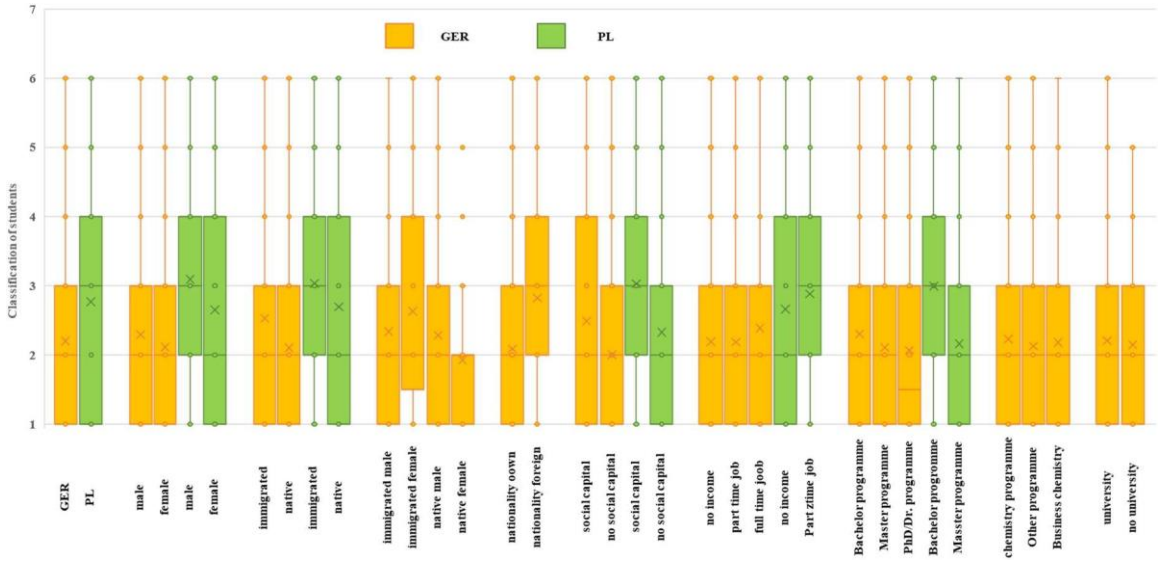

Figure 5.
BOXPLOT ENTREPRENEURIAL INTENTIONS ALL SUBGROUPS IN GER AND PL

When using analysis methods, it is advisable to check the data quality in advance, such as the normal distribution. As this was not completely given for all variables, comparisons were made using the respective ANOVA models depending on the number of parameters. ODDS ratio regressions were used as a further method of analysis, the results of which are shown in Figure 6 for the chemistry students from GER.

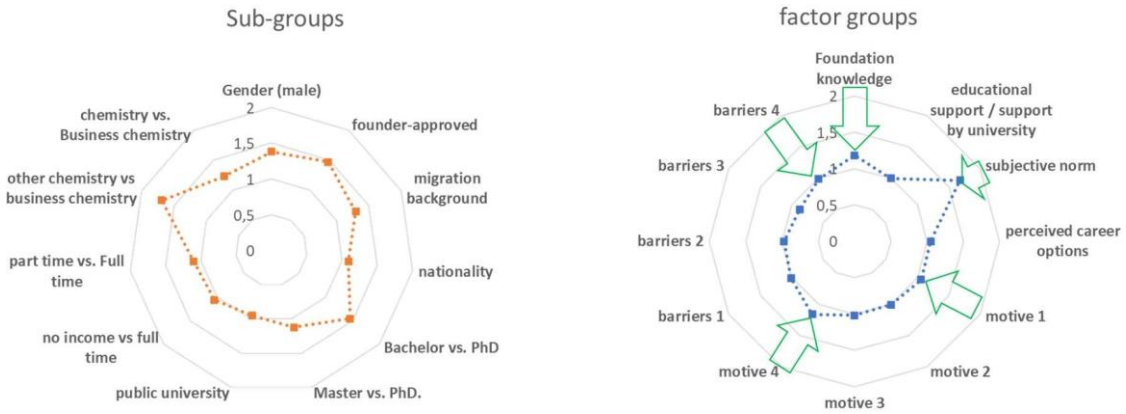

Figure 6
RESULTS ORDINAL REGRESSION GER

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Like the results of the ordinal regression for Germany, the available subpits do not show any significant effects. However, white factor groups consisting of the variables of one group show significant differences. These include "subjective norm", "motive 1", "motive 4" and "barriers 4" (Walther et al., 2024). The ordinal regression was also carried out for chemistry students in Poland and is shown in Figure 7.

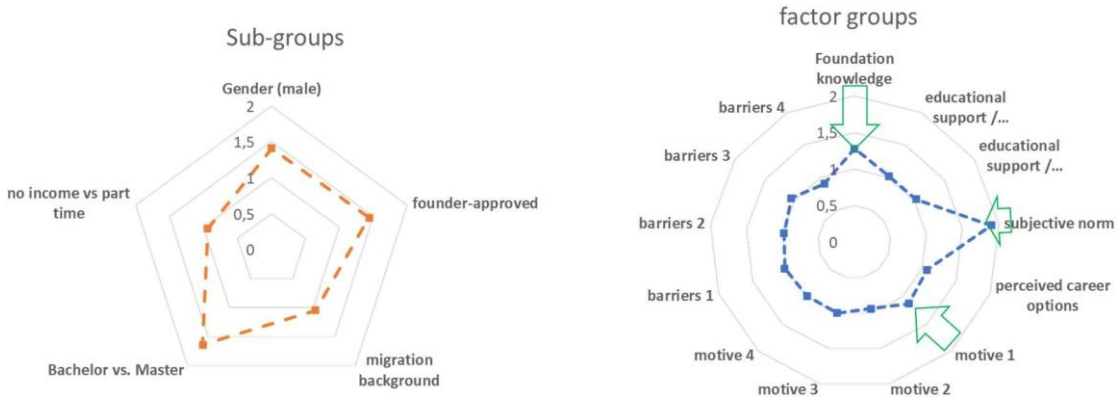

Figure 7
RESULTS ORDINAL REGRESSION PL

Compared to the results from Germany, students from Poland showed no significant effect for the barriers. The significant effects for the subjective norm led to the analysis as an ANOVA for the chemistry students from both countries with social capital as the separating variable (Walther, Haubold, & Dobrucka, 2024). The ANOVA comparison between students with and without social capital shows significant differences in the areas of entrepreneurial intention, foundation knowledge, subjective norm, perceived behavioural control, self-assessment and barriers.

Further individual ANOVA comparisons were carried out for the subgroups of the genders of the two countries, immigration status and immigrated female entrepreneurs as a gender comparison with the additional use of immigrated status (Walther et al., 2024).

Act – Develop EE

Based on the ANOVA comparisons and the ordinal regressions, the EE course is adapted to the students' circumstances. The primary aim was to address chemistry students at a low-threshold level and inform them about the possibilities of setting up a company as a possible career path. Chemistry students in Germany at the beginning of their respective careers in the 1st and 3rd semesters were selected as the starting point, as the ordinal regression estimates undergraduate students to be more willing to start a business. By teaching an experienced founder from his own career combined with company insolvencies and new foundations, possible barriers such as "*the lack of foundation capital*" were to be broken down. At the same time, the aim was to expand foundation knowledge, strengthen motives and break down barriers.

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Plan 2.0 – Plan EE and prepare surveys

In addition to the analogue survey style as in the country comparison survey, the planning of the EE included the application before and after the lessons. To be able to utilise the subjective norm and the social capital, the time between the two surveys was also one week. To ensure comparability of the results, the data should be processed in the same way as before (Walther et al., 2024).

Do 2.0 – Conduct EE and surveys

The students were surveyed digitally via a QR code, analogue to the 1st survey in Germany and Poland. The same exclusion questions and criteria were also used and were analogous to the scheme in Figure 2. The survey had 67 participants before the EE and 51 afterwards, with 64 and 47 responses respectively being analysable and complete.

Check 2.0 – Analysing surveys

Analogous to the results from the country comparison survey, an ANOVA comparison was made between the results of the 1st survey before the EE and after the EE (Walther et al.,). A summary of this comparison can be found as a box plot in Figure 8.

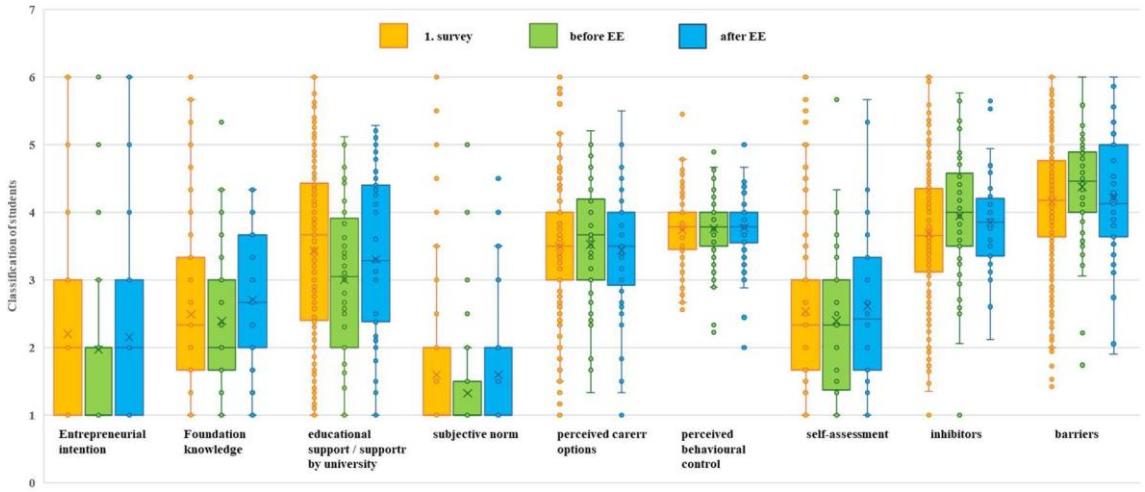

Figure 8

BOXPLOT COMPARISON OF ALL SURVEYS ALL FACTORS IN GER

As Figure 8 suggests, the factor groups EI, foundation knowledge, educational support, subjective norm, self-assessment, motives and barriers show significant differences. In a comparison between before EE and after, the variable groups foundation knowledge, educational support / support by university, perceived career options, perceived behavioural control, self-

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assessment, motives and barriers show significant differences (Walther, Stephan, & Dobrucka, 2024). In addition to the ANOVA comparison, the ordinal regression of the survey results from before EE and after EE was carried out, the results of which are shown as odds ratios in Figure 9.

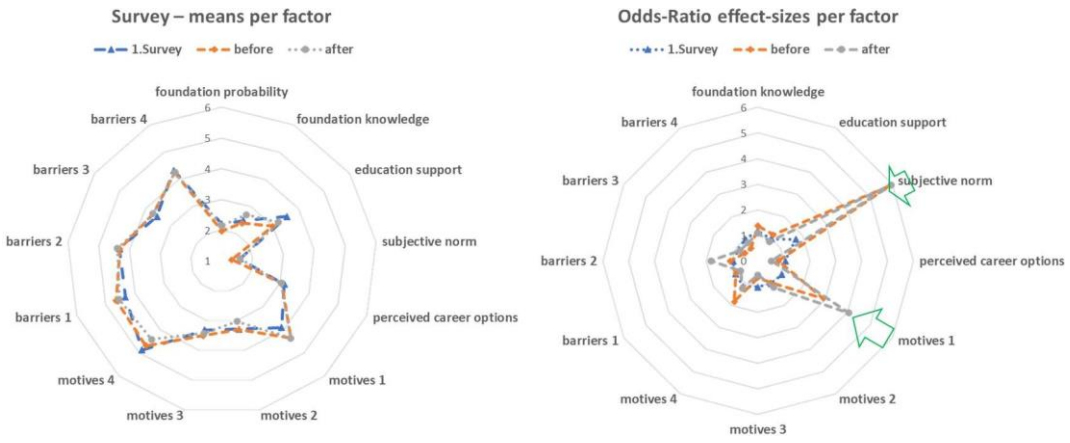

Figure 9
Results comparison ordinal regression all surveys in GER

As the results from Figure 10 show, the students before EE show a significant effect for the factors subjective norm and barriers and after EE only for the motives.

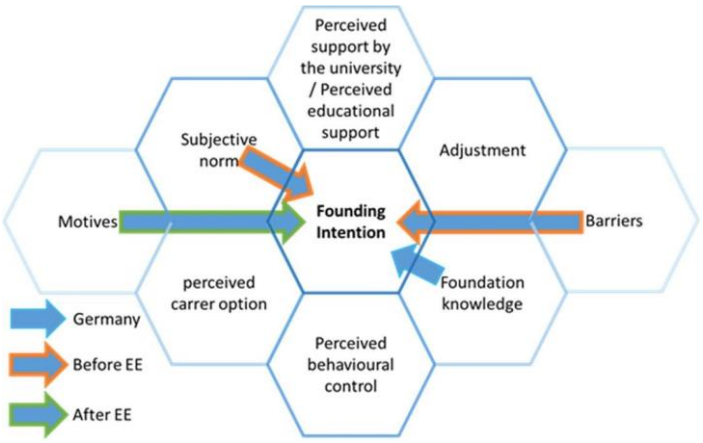

Figure 10.
RESULTS OF ORDINAL REGRESSION AS TPB

DISCUSSION

The study results show a direct influence of factors on the willingness of chemistry students in Germany to set up a company. Differences in the comparison between different countries as well as between different cultures could be demonstrated (Walther,et al., 2024). We therefore

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argue that a comparison should only be made between groups within a cohort, which relates to both a country and the respective study program. At the same time, the comparison between the results from the country comparison survey and the results of the surveys prior to the EE showed that the parameters analysed represent a snapshot in time, which means that data collection is recommended for the respective argumentation. Although no direct significant increase in the willingness of chemistry students in Germany to start a business as a result of participating in EE could be proven, we argue that the significantly higher soft skills in terms of abilities, expertise and a better entrepreneurial attitude (Barringer et al., 2005; Fayolle et al., 2006; Mueller, 2011; Packham et al., 2010), reasons for the non-significant increase in the willingness to start a business may be the low number of participants and the duration of the event. Another possible reason could be the students' attitude towards the course as a traditional formal teaching programme, where the strongest positive link to intentions is visible through the promotion of entrepreneurial self-efficacy.

The hypothesis 'Integrating a PDCA cycle into an entrepreneurship education program improves the methodology for developing and implementing business ideas, enabling students to continuously optimise their entrepreneurial projects and ultimately make them more successful' is therefore accepted.

For further studies, it is therefore recommended that the program be extended to one semester using different teaching methods and learning environments. One possibility could be a combination of existing courses and programmes, such as practical courses like the cooperative innovation strategies (PANDA) of the Fresenius University of Applied Sciences with EE (Wolf, et al. 2021). Other combinations such as marketing or advertising are also conceivable from which students can benefit (Ghafar, 2019). Through these measures, students not only learn the theoretical basics, but also the practical perspectives of starting a business, whereby possible barriers can be broken down and foundation knowledge can be built up. When conducting future studies, a comparison group such as another country or another degree program should also be used to evaluate the effects of EE (Walther, et al., 2024). To review the effectiveness of measures taken, it is advisable to carry out potential analyses such as a GAP analysis (Walther et al., 2023) to derive results. The PDCA cycle is a suitable methodology for the continuous improvement of foundation readiness. The quality of the data as well as the survey or the EE can be achieved through repeated changes and renewed data collection.

LIMITATIONS

The surveys used here are not representative. Although the comparative survey in Germany and Poland has 811 participants, it shows focal points such as regional priorities or democratic shifts. In addition, only students from one university and a small number of students from Germany were included in the survey to analyse the influence of EE. Due to the voluntary nature of the survey and the size of the class, the number of participants in the second survey was 16 fewer. The use of representative surveys is therefore recommended for future analyses. A further limitation may be the number of EE lessons; in the survey used, this was only 2 hours on a voluntary basis, while EE programmes within study programmes account for a higher proportion. For future studies, the use of full EE programmes with sufficient time capacity over the semester is therefore recommended. The personal contact with the students before and after the EE could

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also have increased expectations of the results of the second survey. Another potential bias is the error factor of time between surveys; although it was assumed that students forgot their own answers within a week, there is also a possibility of bias here. The model fit after the entrepreneurship training no longer provided a good fit compared to the survey before the entrepreneurship training or to the data from the first survey (Walther, Haubold, & Dobrucka, 2024). Due to the desired comparability, no further adjustment of the model was made here, but attention should be paid to the smaller group of participants in future studies and analyses when choosing a suitable method of analysis. The online survey was conducted anonymously, which meant that it was not possible to use a longitudinal study with a direct comparison over time, but this is recommended for future analyses.

OUTLOOK

The results of the study could be used to offer EE for STEM study programmes. The use of the PDCA cycle can be utilised to stimulate the desired result in each case. For foundation research, it is also advisable to monitor the effects at regular intervals in the form of GAP analyses such as a potential analysis (Walther et al., 2023). Further adjustments to the research model, such as the target group, are also conceivable for a broader understanding of the foundation behaviour of chemistry students. In addition, the question design can be adapted for a further survey in order to aim for completely normally distributed data, making further analysis methods conceivable.

SUMMARY

This study analyses the use of a PDCA cycle for conducting EE and investigating the willingness of chemistry students in Germany to set up a company. Comparisons are made between the different surveys and the adjustments within a PDCA cycle for this application are explained. The respective data for the results are based on survey data which were analysed using ANOVA comparisons and ordinal regression. The results already show positive developments in the level of knowledge with regard to the understanding of funding organisations after the second round of the PDCA cycle, which in turn indicates a direct influence of entrepreneurship education. At the same time, after EE, students show a greater understanding of the rules of the teaching institution with regard to the transfer of research ideas to foundations, which indicates that the teaching promotes the perception of institutional support. By applying the PDCA cycle, the already analysed effects on chemistry students in Germany, such as the increase in self-perception and entrepreneurial know-how, can be successively increased and expanded through entrepreneurial education. It would also be possible to influence the influencing factor of motives through the future use of EE. Further research and interventions are necessary to improve the effectiveness of teaching, to optimise the survey model and to understand the effects comprehensively.

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