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Experimentation-related causal attributions of German secondary school students

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Abstract: Students' causal attributions play an important role in recent studies due to their effects on academic self-concept and performances. Most common causal attributions are students' ability, effort, task difficulty, and chance. The present study aims at identifying students' preferred causal attributions of failure and success while experimenting. Therefore, the experimentation-related causal attribution questionnaire was developed and used on a sample of 90 upper secondary school students. Its factorial validity, internal consistencies, as well as the autonomy of its eight subscales—success- and failure-related causal attributions based on students' ability, effort, task difficulty, and chance in experimentation—were confirmed. Further analyses revealed a gender difference in experimentation-related causal attributions. Girls show less favourable attribution styles than boys in case of both, success and failure. With regard to experimentation-related successes, boys show a higher attribution to ability than girls. Girls are more likely to use luck and a low degree of task difficulty as an explanation for their academic successes in experimental settings than boys. Female students also draw on attributions such as lack of ability and task difficulty to account for their failures. Practical consequences for science education are derived from the findings.

ABOUT THE AUTHOR

One focus of our research group is to investigate the factors influencing the science-related self-concepts of students and prospective biology teachers. Knowing how these self-concepts are affected is highly relevant, as they in turn affect constructs like motivation and interest. We have recently uncovered the influence of the criterial, social and temporal reference norm on students' experimentation-related self-concept. It is probable that experimentation-related causal attributions are another important influencing factor but there is a lack of suitable instruments to measure this construct. Therefore, in the present study we developed a promising questionnaire to measure students' experimentation-related causal attributions. This may be used in future studies to elucidate the effect of causal attributions on the experimentation-related self-concept. From this, teaching interventions to increase motivation could be derived in order to further develop the quality of science education.

PUBLIC INTEREST STATEMENT

Think back to your science classes. You conducted an experiment. It went completely wrong and you thought it was because of your lack of skills. You got frustrated and you didn´t feel like experimenting anymore. Does this sound familiar to you? Then our study might be interesting for you. We developed a questionnaire that measures the causes students attribute to success and failure while experimenting. Interestingly, girls show less favorable attribution styles than boys. For example, girls are more likely to explain their success in experimentation by luck and a low degree of task difficulty than by their ability, which can lead to demotivation and a low self-concept. This knowledge can help researchers and science teachers to improve future science teaching. By developing strategies illustrating students that successes in experimentation are usually due to their effort and personal ability, more motivating and less frustrating science lessons can be achieved.

Subjects: Teaching & Learning - Education; Educational Research; Education Studies; Science Education

Keywords: causal attributions; questionnaire; experimentation; secondary school students; gender differences

1. Introduction & theoretical background

In academic settings attributions are the causal explanations pupils offer to explain academic successes and failures (Weiner, 1985). Research shows that attributions play an important role in recent theories on motivation, emotion and behaviour (Stiensmeier-Pelster & Heckhausen, 2018; Stiensmeier-Pelster & Schwinger, 2008; Weiner, 1985, 2010). The attributions made by the perceiver have an effect on learning motivation (Legette, 1998; Vezzani et al., 2018), including the effort put into a learning activity, achievement striving and the expectancy of success (Weiner, 1972, 1985). Academic performances (Faber, 2007; McMillan, 2015) as well as behaviours like the degree of persistence in the face of failure (Weiner, 1972), future actions, tasks or career choices (Curdes et al., 2003; Eccles & Wigfield, 1995) are influenced by causal attributions. Furthermore, students' way of attributing certain incidents has an impact on the development of their academic self-concept (ASC) (Faber, 2007; Erten & Burden, 2014; Deters & Hellmich, 2010; Benölken, 2015; Lohbeck et al., 2017).

Students' level of academic performance, such as success and failure can be explained by students' expectancies in regard to how well they will do a task and how important they rate this task (Eccles et al., 1983) or by students' causal attributions. In the social and educational field of research Weiner's (1985) causal attribution theory and his model of achievement-related causal perceptions predominate. Primarily, attribution theory uses causes to explain events and outcomes (Nenty, 2010; Weiner, 1985). The four most common causal factors used to account for achievement-related outcomes are ability, effort, task difficulty and chance (Weiner, 1985, 2010). Besides the affiliation-related dimension of controllability, the causal factors of achievement are described by two intersecting dimensions: locus and stability. The locus of a causal attribution is either allocated within (internal) or outside (external) the actor. Ability and effort are similar in locus, both being internal. Using internal attributions, a student for example ascribes a good grade in a maths exam to her/his high mathematical ability or hard work, while she/he attributes a poor grade to a lack of ability or a lack of effort. In contrast, task difficulty and chance are both externally located factors. Thus, a student can also ascribe a good grade to a simple task or luck. Here, possible explanations for a bad mark are a tasks' high degree of difficulty or bad luck.

The stability dimension refers to whether the attributional causes will still be effective in future expectancies (Weiner, 1985, 2010). Students who explain their good grade by applying a stable factor, i.e. their own ability or task difficulty, expect corresponding grades in the future, whereas pupils who attribute a good grade to effort or luck cannot expect a similar result in the future because the previous grade depended on instable factors. Related literature considers globality as another dimension, which takes into account the generalization of a causal factor across situations and domains (Abramson et al., 1989; Stiensmeier-Pelster & Heckhausen, 2018; Weiner, 2010).

In terms of learning and motivation, a distinction is made between an attribution style that is either self-serving (functional) or self-deprecating (dysfunctional) (Kelley & Michela, 1980; Miller & Ross, 1975), enhancing or obstructing learning and achievement (Stiensmeier-Pelster & Schwinger, 2008; Ziegler & Finsterwald, 2008) and has a motivating or demotivating effect (Rheinberg & Vollmeyer, 2008) in achievement-related situations. In order to enhance a realistic self-concept of capabilities, students should tend to attribute success internally and failure externally (Benölken, 2015; Ziegler & Heller, 2000). A self-enhancing attribution style promotes pupils to feel more confident about their ASC (Banks & Woolfson, 2008; Núñez et al., 2005); conversely, the ASC also has a major influence on causal attributions (Banks & Woolfson, 2008; Bong & Skaalvik, 2003). Because of its predictive power for future success, it deserves as a decision criterion to future course and occupational choices (Curdes et al., 2003; Dickhäuser, 2006; Ertl et al., 2014).

Ample empirical evidence exists concerning the knowledge of younger learners' causal attributions of success and failure (Lohbeck et al., 2017; Ort & Hellmich, 2016; Tiedemann & Faber, 1995). The reciprocal relationship between causal attributions and the ASC has been manifested in an increasing number of studies with younger German learners, as both concepts develop at this age (Benölken, 2015; Dickhauser & Meyer, 2006; Lohbeck et al., 2017). In terms of higher students' causal attributions, most studies have focused on mathematics (Curdes et al., 2003; Mijs, 2016; Shores & Shannon, 2007) or the verbal domain, such as English (Bouchaib et al., 2018; Tan & Chen, 2015; Erten & Burden, 2014). However, up to now, studies with causal attributions of secondary school students is still scarce. More specifically, there is a lack of research that addresses students' causal attributions in experimentation-related situations, although in natural sciences experimentation plays a significant role in scientific literacy (Heinicke & Peters, 2014) and science education (Barzel et al., 2012). Hence, it is manifested in the school curriculum as a core competence for gaining knowledge in science (MSW NRW, 2014). In science education, causal attributions have a far-reaching effect on learning and achievement (Weiner, 1972). Due to the reciprocal relationship of causal attribution, ASC, and motivation (Tan & Chen, 2015; Eccles et al., 1983) a self-deprecating experimentation-related causal attribution is supposed to lead to a low experimentation-related ASC, which in turn could translate into low interest and motivation related to experimental situations. This occurrence of a downward spiral must be prevented in every phase of an experiment. According to the model of experimental skills three dimensions of an experiment can be distinguished: preparation, performance, and data evaluation (Schreiber et al., 2016). Causal factors can be attributed in any of these three phases. Concluding, the knowledge about experimentation-related causal attribution and its effects bear significant implications for the educational sector.

Moreover, past research has shown that there is a gender difference in pupils' general causal attributions of success and failure (Lohbeck et al., 2017). Similar results have been reported for causal attributions in a domain-specific context (Ehm et al., 2011; Lindberg et al., 2013). Girls tend to attribute success in math to external attributions and failure to internal ones, concluding that girls show a more self-deprecating attribution style in math than boys do (Benölken, 2015; Dickhauser & Meyer, 2006; Tiedemann & Faber, 1995; Wolleat et al., 1980). Since experimenting in biology lessons influences boys' interest more than girls' (Gafoor & Narayan, 2012), it can be assumed that experiment-related causal attribution is also gender-specific, which still needs to be verified by empirical research. Thus, to complement to these shortcomings, the present study aims at identifying students' preferred causal attributions of failure and success in experimental-based settings highlighting possible gender differences.

2. Methods

In order to measure students' experimentation-related causal attributions a new questionnaire was deployed. Scale development, sample size, study design and data analysis are described below.

2.1. Scale development

Following Curdes et al. (2003), who measured high school students' attribution of causality for success and failure experiences during their studies, we designed the experimentation-related causal attribution questionnaire (ExCAQ). This newly developed instrument intends to measure the attribution of experimentation-related success and failure to four primarily relevant causal attributions described by the attributional theory (Frieze & Weiner, 1971; Stiensmeier-Pelster & Heckhausen, 2018). The ExCAQ consists of nine short descriptions of successes and nine descriptions of failures related to the dimensions of experimentation (preparation, performance and data evaluation) described by Schreiber et al. (2016). The response options for each description of experimental success or failure consist of four items measuring the attribution to one's ability,

Figure 1. Examples of success and failure related items of the ExCAQ.

If you manage to interprete data from an experiment, the reason is… (success)
I tried really hard. (effort)
I had good luck. (chance)
The task was simple. (task difficulty)
I´m really good in interpreting data. (ability)

If you don´t manage to plan an experiment, the reason is… (failure)
I just had bad luck. (chance)
The task was too difficult. (task difficulty)
I´m not good in planning experiments. (ability)
I did not spent much effort in it. (effort)

effort, task difficulty and chance (see example in Figure 1). Thus, the entire questionnaire consists of eight subscales. Four subscales containing nine items each measure the attribution of experimentation-related success to one´s ability (subscale SA), effort (SE), task difficulty (ST) and chance (SC). Another four subscales were designed to measure the attribution of experimentation-related failure to one´s ability (FA), effort (FE), task difficulty (FT) and chance (FC). The questionnaire (ExCAQ) was conducted in German. The following examples were translated into English. The responses were five-point Likert scales ranging from 0 (strongly disagree) to 4 (strongly agree).

2.2. Sample size and study design

The participants were students of German upper-level grammar schools (secondary level II) visiting biology courses. We consciously chose older pupils because they were allowed sufficient time to experience successes and failures in classroom experiments during the course of their school career. Furthermore, it is unlikely that rather young pupils are able to clearly differentiate a concept like ability from related concepts such as effort, luck and task difficulty (Nicholls, 1987). A total of 90 students completed the survey. Of these were 53 females and 37 males. The ExCAQ was used to measure their experimentation-related causal attribution with one single time of measurement. The processing time was about ten to fifteen minutes.

2.3. Data analysis

Data analysis was performed using SPSS 27. Missing values and outliers were detected. Scores greater than three times the interquartile range (IQR) are considered as extreme outliers which were excluded from the analysis. The Kaiser-Meyer-Olkin (KMO) measure and the Bartlett´s test of sphericity were conducted to examine the adequacy of the sample and the suitability of data for exploratory factor analysis (EFA). A KMO > 0.5 (Kaiser & Rice, 1974) and a significant Bartlett´s test (Bartlett, 1951) are considered suitable for a factor analysis. An EFA (principal component analysis, varimax rotation) with eight given factors was carried out. The number of factors is based on the four causal attributions (ability, effort, task difficulty and chance) explaining both success and failure during experimentation. Even if the items of the ExCAQ were derived by theoretical means they needed to be phrased completely new due to a lack of comparable instruments measuring experimentation-related causal attributions. Therefore, it appeared that an EFA was more convenient than a confirmatory factor analysis. We looked for an "elbow" in the scree plot to confirm the number of factors (Beavers et al., 2013). The percentage of explained variance was calculated. Items which loaded highly on a common factor were assigned to one scale. Items with non-explainable factor loadings, loadings ≥0.4 on a second factor (e.g. Noormann, 2017) or communalities <0.5 (Demirhan & Anwar, 2014) were excluded. Low factor loadings <0.3 (Fromm, 2012) are not reported. Internal consistency was measured by calculating Cronbach's alpha and the item-total correlation. Item-total correlations of $r_{i,t-i}$ >0.4 (Fisseni, 1997) and Cronbach's alpha >0.7 (Schmitt, 1996) are considered suitable. The

Kolmogorov–Smirnov test was conducted to test normality for all eight causal attribution scales. Interscale correlations (Spearman's ρ) were also calculated to study the relationships between the scales. Finally, Mann–Whitney U tests were conducted to detect possible gender differences in the experimentation-related causal attributions.

3. Results

There are no missing values in the dataset. Extreme outliers are only present in two items (SeI1, SeD2). Both items have a very low variability (IQR = 0). These low range items do not provide much information because factor analysis describes joint variations between items. As a consequence, we did not delete the outliers but we excluded both items for further analysis. The KMO (KMO = 0.64) and Bartlett´s test ($\chi^2(2415, N = 90) = 6313.44$; $p \leq .001$) confirm the suitability of the dataset for conducting an exploratory factor analysis. A less pronounced elbow in the scree plot supports the eight-factor structure of the ExCAQ cautiously. These eight factors explain 68.24% of the variance. The pattern of factor loadings and the communalities are provided in Table 1 (success-related items) and 2 (failure-related items).

As shown in Tables 1 and Tables 2 most of the items representing a joint construct are loading clearly on a common factor. None of the failure-related items shows unexpected factor loading or loading ≥0,4 on an additional factor, whereas one of the items representing the attribution of success to ability (SaI3) as well as four items measuring the attribution of success to chance (ScI2, ScD1, ScD2, ScD3) have got a loading ≥0,4 on a second factor. Of particular note is that all of these four items are loading on a common factor with the items measuring the attribution of failure to chance. All aforementioned items were excluded from the analysis. Six additional items (SaP2, SaI2, ScP3, StP1, FaP3, FaI2) were removed because of communalities $h^2 < 0{,}5$. The remaining items were used to derive the following scales: attribution of success to ability (SA), attribution of success to effort (SE), attribution of success to task difficulty (ST), attribution of success to chance (SC), attribution of failure to ability (FA), attribution of failure to effort (FE), attribution of failure to task difficulty (FT), attribution of failure to chance (FC). In consequence of item-total correlations of $r_{i,t\text{-}i} > 0{,}4$ and Cronbach's alpha > 0,7 no further items had to be deleted (see Tables 3 and Tables 4).

As assessed by the Kolmogorov-Smirnov test only ST ($p = .384$), SA ($p = .074$) and FE ($p = .078$) are approximately normally distributed, whereas SE ($p \leq .05$), SC ($p \leq .01$), FA ($p \leq .01$), FC ($p \leq .01$) and FT ($p \leq .05$) were not. Moderate Spearman intercorrelations from $r = -0.32$ to $r = 0.52$ point to the autonomy of the scales (see Table 5). The highest correlation coefficient of $r = 0.52$ was found between SC and FC.

The Mann-Whitney U test was used to check possible gender differences (see Figure 2). With regard to experimentation-related successes, female students show a significantly lower attribution to ability ($U = 733.00$; $Z = -2.03$, $p \leq .05$), a significantly higher attribution to chance ($U = 544.00$; $Z = -3.60$, $p \leq .001$) and to task difficulty ($U = 602.00$; $Z = -3.11$, $p \leq .01$) than the males. In terms of experimentation-related failure female students have a significantly higher attribution to ability ($U = 478.00$; $Z = -4.13$, $p \leq .001$) as well as a significantly higher attribution to task difficulty ($U = 725.50$; Z = −2.09, $p \leq .05$) than the male students.

4. Discussion

As demonstrated, the newly developed ExCAQ shows a well-supported factorial validity as well as highly satisfactory internal consistencies of its subscales. Only the separation of both scales representing the attribution of success or failure to chance is not quite clear if all items were included. We consequently excluded the items with unexpected factor loadings and communalities in the present study. Further research will show, whether this uncertainty depends on the wording of these items, if it may not be appropriate to distinguish between success and failure-related causal attributions in the case of chance, or if it is just an effect of the sample. Several times, it has already been stated that success-related causal attributions should be collected and analysed separately from failure-related causal attributions due to the indication of the existence of two separate constructs (e.g. Crandall et al., 1965; Wolleat et al., 1980). However, some studies using causal attribution questionnaires in contexts different from

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Table 1. Results of the EFA (principal component analysis, varimax rotation)**: Factor loadings and communalities of the success-related items (Acronyms: S = success, e = effort, a = ability, c = chance, t = task difficulty, P = preparation of an experiment, I = performing an experiment [implementation], D = data evaluation, 1 to 3 = item number, *h*2: communalities; a_1 to a_8: factors, *: item excluded cause of factor loadings ≥0,4 on a second factor or communalities <0,5 [in bold], loadings <0.3 not shown)**

	Factor loadings								Communalities
Item	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	h^2
SeP1								.68	.59
SeP2								.71	.60
SeP3								.72	.58
SeI2								.65	.58
SeI3								.79	.72
SeD1								.75	.72
SeD3								.85	.78
SaP1							.68		.54
SaP2*							.62		**.49**
SaP3							.69		.61
SaI1							.72		.60
SaI2*							.50		**.40**
SaI3*							.52	**.41**	.56
SaD1							.71		.55
SaD2							.77		.67
SaD3							.68		.55
ScP1						.69			.56
ScP2						.71			.64
ScP3*	.30				.36	.35			**.49**
ScI1	.37					.68			.71
ScI2*	**.40**					.66			.65
ScI3	.38					.74			.73

(*Continued*)

Table1. (*Continued*)

	Factor loadings								Communalities
Item	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	h^2
ScD1*	**.40**					.69			.70
ScD2*	**.40**					.72			.77
ScD3*	**.45**					.64			.76
StP1*				.51					**.33**
StP2				.65					.53
StP3				.71					.67
StI1				.81					.76
StI2				.77					.77
StI3				.79					.75
StD1				.83					.80
StD2				.70					.64
StD3		.34		.78					.78

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Table 2. Results of the EFA (principal component analysis, varimax rotation): **Factor loadings and communalities of the failure-related items (Acronyms: F = failure, e = effort, a = ability, c = chance, t = task difficulty, P = preparation of an experiment, I = performing an experiment [implementation], D = data evaluation, 1 to 3 = item number, h_2: communalities; a_1 to a_8: factors, *: item excluded cause of factor loadings ≥0,4 on a second factor or communalities <0,5 [in bold], loadings <0.3 not shown)**

	Factor loadings								Communalities
Item	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	h^2
FeP1		.69							.65
FeP2		.87							.84
FeP3		.84							.82
FeI1		.89							.85
FeI2		.92							.90
FeI3		.88							.87
FeD1		.90							.87
FeD2		.91							.87
FeD3		.91							.85
FaP1					.58				.52
FaP2					.62				.61
FaP3*					.57				**.48**
FaI1					.75				.63
FaI2*					.62				**.48**
FaI3					.69				.65
FaD1			.34		.62				.62
FaD2					.67				.62
FaD3			.35		.69				.65
FcP1	.77								.67
FcP2	.86								.84
FcP3	.84								.75
FcI1	.84								.75

(Continued)

Table2. (*Continued*)

	Factor loadings								Communalities
Item	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	h^2
FcI2	.81								.76
FcI3	.84								.79
FcD1	.87								.82
FcD2	.88								.84
FcD3	.86								.82
FtP1			.69						.64
FtP2			.69						.63
FtP3			.68						.59
FtI1			.81						.78
FtI2			.78						.67
FtI3			.76						.78
FtD1			.70						.71
FtD2			.83						.84
FtD3			.82						.75

Table 3. Item and scale values of the success-related attributions

				Percentile		
Scale	**α**	**Item**	**25%**	**Median**	**75%**	$r_{i,t-i}$
success effort (SE)	.89	SeP1	2.00	3.00	4.00	.65
		SeP2	2.00	3.00	3.00	.61
		SeP3	2.00	3.00	3.25	.65
		SeI2	2.00	3.00	3.00	.68
		SeI3	2.00	3.00	3.00	.74
		SeD1	2.00	3.00	3.25	.73
		SeD3	2.00	3.00	4.00	.81
		Scale	*2.43*	*2.86*	*3.29*	
success ability (SA)	.85	SaP1	2.00	2.00	3.00	.61
		SaP3	1.00	2.00	3.00	.65
		SaI1	2.00	3.00	3.00	.67
		SaD1	2.00	2.00	3.00	.59
		SaD2	2.00	3.00	3.00	.68
		SaD3	2.00	3.00	3.00	.62
		Scale	*2.00*	*2.33*	*2.83*	
success chance (SC)	.84	ScP1	.00	1.00	2.00	.59
		ScP2	.75	1.00	2.00	.69
		ScI1	.00	1.00	2.00	.73
		ScI3	.00	1.00	2.00	.68
		Scale	*.69*	*1.13*	*2.00*	
success task difficulty (ST)	.93	StP2	2.00	2.50	3.00	.66
		StP3	2.00	3.00	3.00	.69
		StI1	2.00	3.00	3.25	.78
		StI2	2.00	3.00	3.00	.82
		StI3	2.00	2.00	3.00	.83
		StD1	2.00	3.00	3.00	.83
		StD2	2.00	3.00	3.00	.72
		StD3	2.00	3.00	3.00	.81
		Scale	*2.00*	*2.50*	*3.00*	

N = 90, $r_{i,t-i}$: Item-total correlations

experimentation did not separately examine the theoretically assumed distinction between the success and failure dimension (e.g. Elig & Frieze, 1979; McAuley et al., 1992; Meyer, 1980). The existence of two separate, externally located attributions (task difficulty, chance) is also not clearly supported in some other contexts (e.g. Campbell, 1996; Curdes et al., 2003; Fyans & Maehr, 1980; Marsh & Al, 1984; Nokelainen et al., 2007; Wolleat et al., 1980). Nevertheless, the present data indicate that a distinction between the attribution of experimentation-related success and failure to one´s ability, effort and task difficulty as well as a separation of the externally located attributions make perfect sense in an experimentation-related context. Perhaps it is a consequence of the well-structured experimentation-based science lessons (Barzel et al., 2012; Emden et al., 2016; Schultz et al., 2012) that in students' perception chance is not regarded as a particularly relevant cause of both, experimentation-related success and failure (see Figure 2). Another reason for this might be pupils' perceived controllability. Controllability is—next to stability and locus—another dimension for classifying causal attributions (Meyer, 1980; Stiensmeier-Pelster & Heckhausen, 2018; Weiner, 1985), which we did not include in the ExCAQ. From ninth to twelfth grade students' locus of control becomes less and less external (Chubb

Table 4. Item and scale values of the failure-related attributions

				Percentile		
Scale	**α**	**Item**	**25%**	**Median**	**75%**	$r_{i,t\text{-}i}$
failure effort (FE)	.97	FeP1	1.00	2.00	3.00	.72
		FeP2	1.75	2.00	3.00	.87
		FeP3	1.00	2.00	3.00	.87
		FeI1	1.00	2.00	3.00	.90
		FeI2	1.00	2.50	3.00	.93
		FeI3	1.00	2.00	3.00	.90
		FeD1	1.00	2.00	3.00	.91
		FeD2	1.00	2.50	3.00	.90
		FeD3	1.00	2.00	3.00	.89
		Scale	*1.22*	*2.22*	*3.00*	
failure ability (FA)	.88	FaP1	1.00	1.00	2.00	.61
		FaP2	1.00	2.00	2.00	.66
		FaI1	1.00	2.00	2.00	.65
		FaI3	1.00	2.00	3.00	.66
		FaD1	1.00	2.00	3.00	.75
		FaD2	1.00	2.00	3.00	.70
		FaD3	1.00	2.00	3.00	.67
		Scale	*1.11*	*1.86*	*2.29*	
failure chance (FC)	.96	FcP1	.00	1.00	2.00	.72
		FcP2	.00	1.00	2.00	.86
		FcP3	.00	1.00	2.00	.83
		FcI1	.00	1.00	2.00	.81
		FcI2	.00	1.00	2.00	.82
		FcI3	.00	1.00	2.00	.85
		FcD1	.00	1.00	2.00	.88
		FcD2	.00	1.00	2.00	.88
		FcD3	.00	1.00	2.00	.86
		Scale	*.22*	*1.00*	*1.89*	
failure task difficulty (FT)	.94	FtP1	2.00	3.00	3.00	.73
		FtP2	1.00	2.00	3.00	.70
		FtP3	2.00	3.00	3.00	.69
		FtI1	2.00	3.00	3.00	.82
		FtI2	1.75	2.00	3.00	.70
		FtI3	2.00	3.00	3.00	.83
		FtD1	2.00	3.00	3.00	.70
		FtD2	2.00	3.00	3.00	.88
		FtD3	2.00	2.00	3.00	.80
		Scale	*1.86*	*2.56*	*2.92*	

N = 90, $r_{i,t\text{-}i}$: Item-total correlations

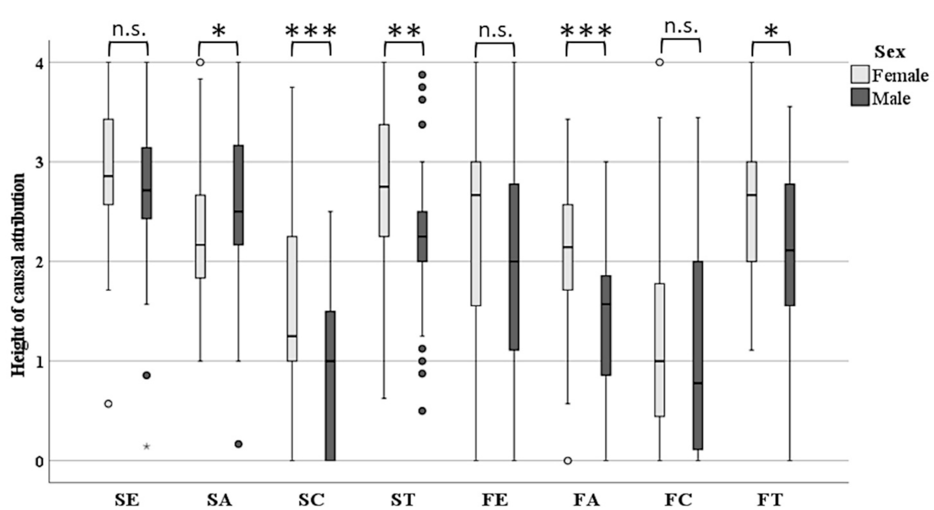
Table 5. Scale intercorrelations (**p* ≤ .001, ***p* ≤ .01, **p* ≤ .05)**

	SE	SA	SC	ST	FE	FA	FC
SE	1						
SA	.33***	1					
SC	−.01	−.14	1				
ST	.05	−.20	.39***	1			
FE	.25**	.04	.11	.43***	1		
FA	.05	−.32**	.35***	.42***	.32**	1	
FC	.03	.03	.52***	.14	.04	.26*	1
FT	.13	−.08	.24*	.44***	.28**	.47***	.26*

et al., 1997). Since there is a positive correlation between perceived problem-solving skills and internal locus of control (Çakir, 2017), it is conceivable, that older pupils as given in the present sample, who have already conducted some experiments during the course of their school career, perceive higher experimental skills and therefore a more internal locus of control. Hence, chance as an external locus of control is not a particularly preferred causal attribution. This could also be a plausible explanation to the observed gender differences (Figure 2): Consistent with studies in other contexts (e.g. Wolleat et al., 1980; Benölken, 2015; Lohbeck 2017), female students have a rather self-deprecating attribution style in the context of experimentation than boys. In particular, they show a significantly lower attribution to ability in case of experimentation-related successes and a highly significant higher attribution to ability in case of experimentation-related failure. It is conceivable, that this also depends on gender differences in the perceived locus of control because internality appears to be more related to achievement for males than females (Sherman et al., 1997). In view of the above, it would be interesting to separate causal attributions from perceived control of causal attributions in further research as proposed by Maes (1995).

Upcoming research also has to show the criterion validity of the ExCAQ because this was not addressed in the present study. It can be assumed that the internal experimentation-related causal attributions in particular significantly correlate with external criteria like experimentation-related self-concept (Atzert et al., 2020), self-efficacy in doing experiments, and experimental achievement, since studies in other contexts demonstrated considerable relationships between attributions and these constructs (Pishghadam & Zabihi, 2011; Stajkovic & Sommer, 2000; Tabassam & Grainger, 2002). ASC seems to be positively correlated to success-related ability attributions and negatively to failure-

Figure 2. Gender differences in experimentation-related causal attributions (**p* ≤ .001, ***p* ≤ .01, **p* ≤ .05, n.s. = not significant).**



related ability attributions, for instance. In the case of effort attribution correlations seem to be similar but not to such a great extent (Marsh & Al, 1984). More than that, it might even be a causal, reciprocal relationship between ASC and academic attributions (Marsh & Al, 1984). Due to the declining scientific self-efficacy and interest of, especially female, pupils (Schiepe-Tiska et al., 2016), a possible effect of experimentation-related causal attribution on the experimentation-related self-concept seems to be highly relevant for science education, as it offers a chance to counteract this negative trend through adequate teaching. A source of attributional information about ability and effort in experimentation-based science lessons may not only be the implicit feedback of a successful or unsuccessful experiment. Another source can be the explicit feedback from the teacher (see also Graham & Chen, 2020) on how pupils plan, perform and evaluate an experiment. Attributional feedback from others that links performance outcomes to ability and effort, respectively failures to a lack of effort, seems to be a suitable indirect way to increase students' ASC through self-attributions (Craven et al., 1991; Penn et al., 2001; Schunk, 1983). Moreover, there are hints that the effects of attributional feedback seem to be persistent (Rascle et al., 2015). The ExCAQ offers a way to explore these conceivable effects of experimentation-based science education and teacher feedback on students' experimentation-related causal attributions. Furthermore, it provides the opportunity to clarify the connection to related constructs such as experimentation-related self-concept and self-efficacy in doing experiments, which have hardly been investigated so far. Thus, this study not only provides a significant contribution to the quality development of experimental science teaching in schools. It also highlights gender gaps in the experimentation-related causal attributions that need to be addressed.

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Ethics declaration
All the authors mentioned in this manuscript have agreed for authorship. This manuscript has neither been published nor submitted anywhere else. All participants of the study were informed of the voluntary nature and the anonymity. They gave their written agreement to take part in the research before the completion of the questionnaires. The ethic committee of the University of Wuppertal has approved this study (approval number: 210,401).

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