# DOMAIN-SPECIFIC THEORIES OF INTELLIGENCE: HOW STUDENTS' MINDSETS IN PHYSICS CHANGE WITHOUT INTERVENTIONS

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*Implicit theories about intelligence influence students' goal setting, their engagement in learning and their academic performance. Whether students believe in the fixedness versus malleability of intelligence, they are referred to as holding a fixed versus a growth mindset. Research shows the benefit of a growth mindset especially in an academic context, and how interventions can foster a growth mindset. But a surprisingly small number of studies examined the changeability of mindset over time without an intended intervention. This study aims to survey physics specific mindsets which students hold from the first year of physics lessons to graduation class. N=900 students from academic high schools in Germany participated in this survey and four different mindset types could be identified: a growth mindset, two types of fixed mindset (one holding the fixedness of general intelligence accountable for physics success and one believing in a special giftedness in physics) and a mixed mindset including those beliefs that do not fit the mindset theory. The change in the mindset distribution over the different grades indicate an influence of learning physics on the beliefs students hold about this subject. Also, as indicated in other mindset studies and research concerning different non-cognitive factors in physics, there is a gender-specific differentiation measurable in physics specific mindsets.*

## INTRODUCTION

Students vary in their beliefs about the nature of intelligence. Since these beliefs are often unconsciously held, they are also referred to as implicit theories of intelligence. Entity theorists believe that intelligence is a fixed trait, and one cannot change it (fixed mindset). Incremental theorists on the other hand, believe that intelligence is malleable and can always be developed through effort (growth mindset) (Dweck, 1999). Students with a growth mindset show a preference for challenging tasks; they choose learning goal tasks over performance goal tasks, and they show a mastery pattern of behavior and higher engagement in learning (e.g. Blackwell et al., 2007; Yeager et al., 2019). Research on mindset theory shows that one's beliefs about the fixedness or malleability of traits are not global. For example, Cheng & Hau (2003) report that students hold differentiated mindsets on intelligence, personality, creativity, and emotional intelligence. There are only a few studies examining students' mindsets in different academic domains, but they implicate a tendency of a more fixed view on STEM subjects (e. g. Cimpian et al., 2007; Jonsson et al., 2012; Leslie et al., 2015; Meyer et al., 2015). Also, some data reports gender-specific differences in implicit theories, e. g. Gunderson et al. (2013) found girls to be more likely to hold a fixed mindset and Archer et al. (2020) found that especially female students strongly believe in a natural ability in physics as a premise for success. While a majority of mindset research is focused on interventions to foster an incremental belief, there is only limited knowledge about changes in distributions of incremental and entity beliefs in different age groups, and especially domain specific. Since such knowledge would allow a more targeted setting of growth mindset interventions, the present study aims to investigate physics learners' mindset distributions in different age groups: How do students' domain specific beliefs about fixedness versus malleability of their physics-ability change without the influence of a mindset intervention?

# THE STUDY

To address student's domain specific theories of intelligence in physics, N = 1606 students from different secondary schools in Hesse (Germany) participated in a pen and paper mindset survey between November 2019 and February 2020, while for the purpose of better comparability only the subgroup of N = 900 (430 of them female) students from the participating 12 academic high schools are considered. Students from seventh grade, which is the first year of physics lessons in Germany, to graduation class had been participating, to examine the whole age span of physics learners. The mindset survey contains the commonly used four items of the "Theories of Intelligence Scale" (Dweck, 1999), asking about students' beliefs about general intelligence, e. g. "You have a certain amount of intelligence and really can't do much to change it" ($\alpha$ = .80). To focus on the students' physics specific beliefs two more scales have been developed. The scale "Giftedness in Physics" consists of four items such as "You need a certain giftedness for being successful in physics" ($\alpha$ = .81). The other scale with seven items is labelled as "Effort in Physics" ($\alpha$ = .83) and contains statements like "Everyone can understand physics, you just have to put in enough effort" (Goldhorn et al., 2020).

To identify students' physics specific mindsets a hierarchical cluster analysis (Ward's method with squared Euclidean distances) was conducted using the average ratings of the three scales. Four types of physics specific mindsets can be identified, two of them are manifestations of a fixed mindset. Students with a *fixed mindset "general intelligence"* believe that general intelligence as a fixed trait is accountable for one's success in physics. Students with a *fixed mindset "giftedness in physics"* believe in a domain specific giftedness, a special talent in physics, that is necessary for one's success in this area. Students with a *growth mindset in physics* neither believe in intelligence as a fixed trait nor that one needs a special giftedness in physics to be successful. The fourth cluster is called a *mixed mindset* since it doesn't fit the characteristics of a growth or a fixed mindset.

# RESULTS

Overall, 45.8 % of the participating students hold a growth mindset in physic, 16.2 % hold a fixed mindset "general intelligence" and 13.7 % a fixed mindset "giftedness in physics". 24.3 % of the students don't match the criteria for fixed or growth mindset and are therefore assigned to the mixed mindset. For more detailed results, table 1 shows the mindset distributions ordered by grade.

**Table 6. Mindset distributions for different classes from seventh grade to graduation class.**

| | *fixed mindset "general intelligence")* | *fixed mindset "giftedness in physics"* | *mixed mindset* | *growth mindset* |
|---|---|---|---|---|
| *7th grade* | 13.8 % | 4.3 % | 12.8 % | 69.1 % |
| *8th grade* | 16.2 % | 13.4 % | 26.9 % | 43.5 % |
| *9th grade* | 19.8 % | 10.1 % | 28.6 % | 41.5 % |
| *10th grade* | 17.9 % | 19.0 % | 24.4 % | 38.7 % |
| *introductory phase* | 9.7 % | 16.7 % | 13.9 % | 59.7 % |
| *graduation class* | 12.8 % | 18.0 % | 27.1 % | 42.1 % |

The youngest participants are in seventh grade, since physics lessons in Hesse (Germany) start in this grade. While 69.1 % of the seventh-grade students hold a growth mindset in physics after only a few months of learning experience in this subject, the growth mindset percentage decreases during the following years. The largest gap is between seventh and eighth grade (from 69.1 % to 43.5 %) and the minimum of the growth mindset percentage is in the last year of middle school (tenth grade) with only 38.7 %. During the same time, the number of students holding a physics specific fixed mindset (the so-called fixed mindset "giftedness in physics") is drastically increasing. Only 4.3 % of the participating seventh graders hold this mindset, but after just one year of physics learning the percentage of the fixed mindset "giftedness in physics" is up to 13.4 % in eighth grade. And while the growth mindset percentage has its minimum in tenth grade, the fixed mindset "giftedness in physics" is at its maximum with 19.0 % at the same time. Besides the changes in the mindset distribution during middle school also the percentages in introductory phase are noticeable. Introductory phase is the first year of the upper school level. The number of students holding a growth mindset increases in this grade to 59.7 %, the next highest percentage after starting physics classes. But this much stronger growth mindset does not seem to be long-lasting and in the next grade, graduation class, the growth mindset percentage is decreasing to 42.1 % which is not significantly higher than in middle school.

The following diagrams are showing the changing percentages of growth mindset (figure 1) and fixed mindset "giftedness in physics" (figure 2) comparing female and male students. The girls start physics lessons with a higher percentage of growth mindset (72.7 %) than the boys (63.2 %). In ninth grade the growth mindset percentage is the same for female and male students (42.1 %) and in higher classes there is a larger percentage of boys holding a growth mindset in physics.

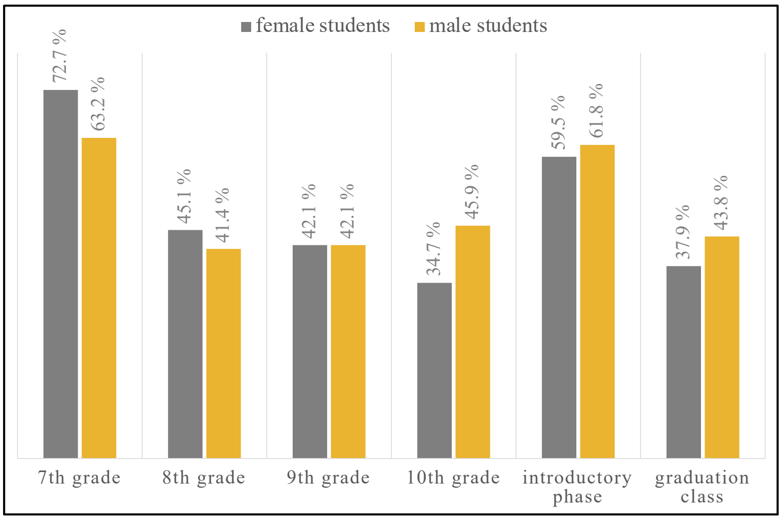


**Figure 5. Growth mindset percentage for different grades, comparing male and female students.**

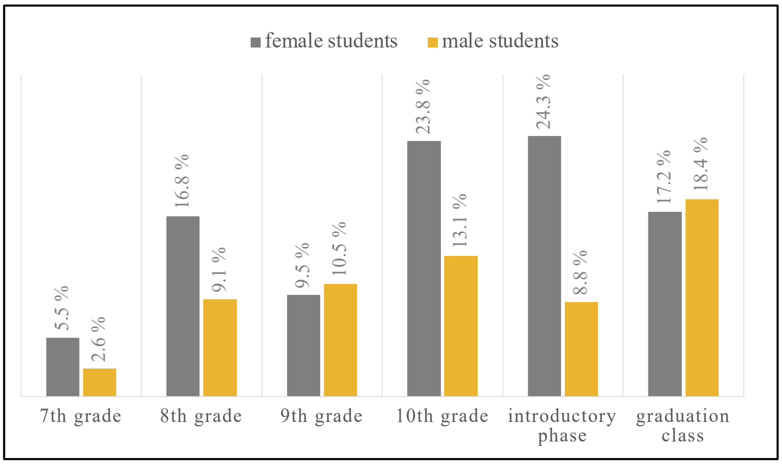


**Figure 6. Fixed mindset "giftedness in physics" percentage for different grades, comparing male and female students.**

# DISCUSSION

Since there are students from seventh grade to graduation class participating in this study, the results show how students' mindsets in physics are changing over time. There are three main findings.

1. *Over the years the growth mindset percentage decreases and students show a higher percentage of fixed mindset in graduation class relatively to the first year of physics.*

While in seventh grade, when starting with physics lessons, there is a high percentage of students holding incremental beliefs (69.1 % in seventh grade), this growth mindset percentage decreases drastically over the next years. Similar findings are reported for domain-general mindsets, comparing the percentage of students with incremental beliefs in high school versus late elementary school (Cheng & Hau, 2003). Also, for domain-specific mindsets in math a decrease of the growth mindset is reported by Gunderson et al. (2017). Since there is some literature suggesting a higher percentage of fixed beliefs in STEM fields for adults (e.g. Jonsson et al., 2012; Meyer et al., 2015), monitoring mindset distributions over time is interesting in order to learn more about the development of the implicit theories. Our data indicates that this fixed mindset tendency in STEM is not given from the beginning but evolves with more exposure to physics lessons.

2. *The biggest mindset shift is observable during the first year of physics lessons.*

Looking more closely at the results of our study, the numbers show that there is a sharp decline of growth mindset percentage between the seventh and eighth grade (from 69.1 % to 43.5 %). Limeri et al. (2020) showed that undergraduate students' domain specific incremental beliefs decrease when faced with a challenging STEM-course. Physics lessons in general are described as challenging (e.g. Ornek et al., 2008), so middle scholars' beliefs may be influenced by starting physics classes in the same way. This, again would support the hypothesis that students' mindsets are influenced by physics lessons and are not just changing age-dependent during middle and high school.

3. *Girls hold stronger beliefs about an innate talent for physics.*

Comparing the gender specific mindset distributions, our results indicate that girls hold stronger beliefs about a fixed giftedness in physics (compare figure 2). And, as well as the sharp decline of the incremental belief during the first year of physics, there is a sharp increase in the domain-specific entity beliefs visible: the percentage of fixed mindset "giftedness in physics" rises from 5.5 % to 16.8 % for female students and from 2.6 % to 9.1 % for male students. These results are consistent with other studies asking about students' beliefs about talent in physics, e. g. Archer et al. (2020). In the first years of physics learning, the percentage of girls holding incremental beliefs is higher than the percentage of boys, but this changes from ninth grade onwards, when more boys tend to have a growth mindset. Several studies are supporting this result and found that boys held more incremental beliefs than girls (e.g. Gunderson et al., 2013). But there are also studies showing no gender specific differences (e.g. Gunderson et al., 2017). So, it will be important to examine this further and get more knowledge on the circumstances of possible gender differences in (domain-specific) mindsets.

# CONCLUSION

In this study we reported students' domain-specific mindsets and how they change over time without any intervention taking place. Students' beliefs about the fixedness versus malleability of physics ability changes throughout their school years, and male and female students show a higher percentage of fixed beliefs in graduation class relatively to the first year of physics lessons. Even though there is no gender difference in the overall trend of an increasing domain-specific fixed mindset and a decrease of the growth mindset, girls seem to hold stronger beliefs about a fixed and innate talent in physics. The biggest shift in mindsets is visible between the seventh and eighth grade, while physics as a new school subject is introduced in seventh grade. Being faced with this new subject, often reported as challenging, seems to strengthen students' domain-specific entity beliefs about intelligence and ability. These findings are consistent with the results of other studies about fixed and growth mindset, especially with research concerning the STEM-field and mindset. Since the present study only collected data about physics specific mindset, we cannot say if the observable mindset changes over time are just age-dependent or being influenced by the academic setting and physics lessons in particular. Still, taken research about other non-cognitive factors into account (e. g. Hoffmann et al., 1998) our findings can be interpreted as another indication of physics lessons influencing students' non-cognitive physics related factors.

Overall, our results about these mindset shifts are an important basis for upcoming research on the effectiveness of mindset interventions and to answer the question which age group of students can benefit the most from interventions to foster a growth mindset in physics.

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