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Self-underestimating students in physics instruction: Development over a school year and its connection to internal learning processes

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ABSTRACT

Students' individual cognitive and motivational–affective characteristics play an important role for successful learning but are also influenced by learning processes. For '*self-underestimating*' students, high content knowledge is not met by an according self-concept of ability. This study investigates the development of $N = 360$ of these students over their ninth grade. Furthermore, it explores the connection between their development and their internal learning processes during physics instruction. Internal learning processes included the perceived fulfillment of their basic motivational needs, intrinsic motivation, and cognitive learning activity. Via latent class analysis, three developmental patterns were identified: students (1) whose self-concepts '*improved*' and aligned with their high cognitive characteristics, (2) whose alignment '*remained self-underestimating*', and (3) whose low self-concept prevailed and cognitive advancement '*decreased*'. Findings suggest that positive development is connected with higher internal learning processes. These results indicate that a positive development of '*self-underestimating*' students is possible and should be supported by fostering internal learning processes.

1. Introduction

Students differ regarding their cognitive and their motivational–affective characteristics (Organisation for Economic Co-operation and Development (OECD) (OECD), 2014). Single characteristics such as the self-concept of ability play an important role as prerequisites for student learning (Riding & Rayner, 2001). Oftentimes, however, it is the interplay of these characteristics that makes a difference. Regarding self-concept, for instance, it is highly relevant if a low self-concept is connected with high or with low cognitive characteristics since the accuracy of this self-judgment also influences individual perception and behavior (Dunning, Heath, & Suls, 2004) and, for students, their learning (Dunlosky & Rawson, 2012).

Based on student profiles uncovered by Seidel (2006) for ninth-grade physics students, this study focuses on a particular combination of student characteristics as prerequisites for learning: students with a high level of physics knowledge, yet a low self-concept of ability regarding physics. This group of students is at risk of underestimating their abilities. From an educational perspective, this specific '*self-underestimating*' profile is particularly interesting as it combines a favorable predisposition for teaching, the students' high prior knowledge, with a challenging characteristic, the low motivational predisposition of students. The group's especially high content knowledge indicates that they have high capacities for achieving which is one of the most prominent indicators for learning outcomes (Hattie, 2009). However, as Pintrich, Marx, and Boyle (1993) highlight, learning is not only "cold and isolated cognition". Instead, motivational aspects are crucial for cognitive advancement. Individuals who underestimate their abilities might hold themselves back from engaging in critical situations for development and hence, often fail to live up to their potential (Elliot & Church, 2003). Their teachers therefore must provide support to foster internal learning processes that nourish the students' self-concept – for its own sake as an important outcome of education (Shavelson, Hubner, & Stanton, 1976) and to ensure cognitive development.

The focus on development of motivational–affective abilities in classrooms has long been a focus of research (e.g., Shavelson et al., 1976). However, to our knowledge, research has not focused on the development of students' low self-concept in the light of high content pre-knowledge as well as the development of this group's high cognitive abilities. Furthermore, studies have suggested that students' internal learning processes such as their perceived fulfillment of basic motivational needs, intrinsic motivation, and cognitive learning activity are positively connected to student development (Dweck, Mangels, & Good, 2004). Yet, it is unclear which internal learning processes are connected with the development of students whose subject-related self-concept needs special furtherance at the same time as their high content knowledge must be utilized and nourished.

In this study, we are interested in how students who have been characterized as '*self-underestimating*' in physics instruction at the beginning

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of a school year develop over the course of one school year. Does their self-concept come to align with their high knowledge or does their learning suffer from their weak self-concept? Therefore, we analyze student characteristics data by means of latent class analysis (Hagenaars & McCutcheon, 2002). We want to know which latent classes of students who were characterized as '*self-underestimating*' at the beginning of a school year can be separated at the end of the school year. Furthermore, this study attempts to shed light on the question if a potentially diverging development is connected with the students' internal learning processes. Thus, this study juxtaposes the perceived fulfillment of the three basic motivational needs, the intrinsic motivation, and the level of cognitive learning activity for the '*development groups*' of '*self-underestimating*' students and analyzes differences by nested analysis of variance.

1.1. The interplay of cognitive and motivational–affective student characteristics

Educational research agrees that cognitive and motivational–affective student characteristics are crucial for learning (Snow, Corno, & Jackson, 1996). Students need individual support according to their set of characteristics (Shuell, 1996). Recently, the analysis of a combination of different cognitive and motivational–affective student characteristics, like general cognitive abilities, interest, or self-concept has become the focus of studies like Hornstra, van der Veen, Peetsma, and Volman (2013) or Wormington, Corpus, and Anderson (2012). This contribution refers to a prior study by Seidel (2006) who indicated five different student profiles for physics instruction. The student profiles found at the beginning of the school year show differences in their cognitive abilities and in motivational–affective aspects (an overview can be found in Table 1 (values for MP 1)). Here, the term cognitive abilities refers to the students' general cognitive ability measured by a scale on reasoning abilities (e.g. figure analogies) and the students' subject knowledge assessed by a curriculum-adapted knowledge test developed for the study. Furthermore, we jointly refer to the students' interest in physics and their physics-related self-concept as the students' motivational–affective characteristics.

This study focuses on the development of students of the '*self-underestimating*' profile that exhibits high cognitive abilities and low motivational–affective characteristics. 30% of students were classified as '*self-underestimating*' at the beginning of the school year. Additionally, as two meaningful '*reference groups*' of the Seidel (2006) study, we chose to consider the students that were classified in the overall favorable student profile at the beginning of the school year, the '*strong*' students, and the overall concerning student profile, the '*struggling*' students, in appropriate analyses. Values for their development at the end of the academic year and their internal learning processes during the school year were also calculated and considered to set the development and internal learning of the '*self-underestimating*' group into perspective. Students with a '*strong*' profile had shown high values both for cognitive as well as motivational–affective characteristics. They make up 24% of students at the beginning of the academic year. The 23% of all students who were profiled as '*struggling*' at the beginning of the year had shown low values for all four cognitive and motivational–affective characteristics. Due to their fragmented nature, the remaining two profiles found in the study are not suitable as meaningful reference groups and hence, will not be presented or included in this paper.

1.2. Self-underestimating students: high knowledge but low self-concept

Knowledge is both, the prominent outcome of learning processes and, by influencing how new information is processed and comprehended, crucial prerequisite for learning (Pintrich et al., 1993). The '*self-underestimating*' students, who are in the focus of this study, possess a high level of physics knowledge. From this point of view, they are inclined to easily process and learn during the school year. However, as Pintrich et al. (1993) argue, cognition alone cannot satisfactorily describe learning. Instead, motivational beliefs are also essential. Academic self-concept is conceptualized in multiple models (for a review, see Marsh, 1990a). In this study, we refer to subject-specific self-concept as "a person's perception of himself" (Shavelson et al., 1976). It is influenced by an individual's experiences and environment. For a student's self-concept regarding physics as a school subject, the learning experiences and environment play an important role. Moreover, for the development of students, self-concept is not only a moderator variable for achievement but also an outcome of educational processes itself (Shavelson et al., 1976). For '*self-underestimating*' students, the focus group of this study, a low self-concept is the other defining features. By investigating this specific group's development, this study sheds light on the interaction of high knowledge and a low self-concept.

In the present study referring to German physics instruction, a large group of students (on average 29% per classroom, but in some classrooms up to 65% of students) were classified into the '*self-underestimating*' student profile (Seidel, 2006). Relatively more girls than boys exhibit this combination of cognitive and motivational–affective characteristics (Jurik, Gröschner, & Seidel, 2013). Physics as a subject may play a role. In schools, physics is perceived to be among the most difficult subjects only suitable for strong students (Osborne, Simon, & Collins, 2003).

Table 1
Student characteristics at the beginning and the end of the school year of the three *'self-underestimator development groups'* uncovered by latent class analysis at the end of the school year (values of *reference groups'* included for reference only).

	%	N	Cognitive ability		Beginning of school year (MP 1): Physics knowledge		Interest		Self-concept		End of school year (MP 3): Physics knowledge		Interest		Self-concept	
			M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
'Self-underestimator development groups' identified at the end of the school year																
'Improving self-underestimators'	26%	91	.86	(.10)	.44	(.10)	2.18	(.62)	2.44	(.37)	**.56*****	(.12)	**2.38****	(.68)	**3.03*****	(.32)
'Remaining self-underestimators'	41%	144	.85	(.10)	.43	(.09)	1.94	(.64)	2.15	(.45)	**.55*****	(.09)	**1.81****	(.57)	**2.12**	(.43)
'Declining self-underestimators'	33%	114	.79	(.08)	.37	(.08)	2.14	(.59)	2.10	(.44)	**.36**	(.07)	**2.07**	(.70)	**2.15**	(.52)
All students																
Total		1222	.74	(.20)	.37	(.12)	2.24	(.73)	2.50	(.69)	.45	(.15)	2.19	(.77)	2.51	(.68)
'Reference groups' identified at the beginning of the school year																
'Self-underestimating'	29%	360	.83	(.10)	.41	(.09)	2.06	(.63)	2.20	(.46)	.49	(.13)	2.05	(.68)	2.39	(.59)
'Strong'	24%	295	.88	(.08)	.46	(.10)	2.69	(.75)	3.26	(.38)	.55	(.14)	2.52	(.75)	3.03	(.60)
'Struggling'	23%	280	.52	(.17)	.28	(.09)	1.96	(.63)	1.96	(.46)	.35	(.12)	1.97	(.76)	2.11	(.56)

Note: All students assigned to groups at MP 1: $n_{TL} = 1222$; all *'self-underestimating'* students assigned to groups at MP 3: $n_L = 349$; Significant changes in student characteristics by the end of the school year (MP 3) for the three *'self-underestimator development groups'* (bold values) compared to their values at MP 1 are indicated by * $p < .05$, ** $p < .01$, *** $p < .001$.