Learning and Individual Differences 51 (2016) 119–131

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Underachievement in physics: When intelligent girls fail

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ARTICLE INFO

Article history:
Received 13 November 2015
Received in revised form 29 June 2016
Accepted 11 August 2016
Available online xxxx

Keywords:
Underachievement
Gender differences
Physics education
Science education
Latent profile analysis

ABSTRACT

The present study examined gender-specific physics underachievement to identify highly intelligent students who perform below their intellectual potential in physics. The sample consisted of 316 students (182 girls) from higher secondary school (Gymnasium) in Switzerland (age $M = 16.25$ years, $SD = 1.12$ years). In a multiple group latent profile analysis, intellectual potential and physics grades were used to determine gender-specific student profiles. In accordance with prior expectations, a problematic profile of female physics underachievers with high intellectual potential but below-average physics grades was identified. Their math grades and GPA (Grade Point Average), by contrast, were within the normal range, suggesting domain-specific underachievement. The female physics underachievers, moreover, showed a low interest and self-concept in physics compared with the other students, complementing the picture. An independent sample was used to validate the student profiles. In concluding, we discuss implications for physics classrooms and future research.

1. Introduction

Recent reviews that summarized work on women's science participation identified secondary school as a crucial point in time to consolidate gender differences in achievement, engagement, and interest in science (see Ceci, Ginther, Kahn, & Williams, 2014; Ceci, Williams, & Barnett, 2009). These gender differences are also reflected in the smaller proportion of talented, intelligent females who specialize in science (e.g., Lubinski & Benbow, 1992). Intelligent students who fail to realize their potential, particularly in physics, have become a growing concern in today's competitive, technology-dependent society. In light of the current state of research on the gender gap in physics, there is reason to expect more girls than boys among such physics underachievers. Whereas gender differences have been addressed in terms of both general scholastic underachievement (Colangelo, Kerr, Christensen, & Maxey, 1993) and general physics attainment (e.g., Heilbronner, 2012; Lubinski & Benbow, 1992, 2007), in this study, we investigate gender-specific underachievement in physics (c.f. Adams, 1996; Reis, 1991).

In the present study, we want to contribute to a precise picture of the gender-specific prevalence of underachievers in physics. Profound knowledge about this student group constitutes the basis for further research and school interventions that may reduce the gender gap in physics. By using multiple group latent profile analysis, we propose an innovative statistical approach to identify physics underachievers. Student profiles were defined by a measure of intellectual potential and physics grades. The domain-specificity of physics underachievement was investigated by analyzing the underachieving students' performance in other school subjects. We also examined the physics underachievers' interest and self-concept in physics to describe this group of students further.

To set the stage for this study, in the following sections, we start from the broad perspective of general scholastic underachievement and increasingly zoom in on characteristics of physics underachievers leading to gender differences in physics and, finally, to the research aims of the present study.

2. Operational definitions of underachievement

As a preliminary remark, underachievement research suffers from a similar phenomenon to its objects of study, that is, a failure to exploit its potential. One reason for this failure is the fragmented research base. Definitions of underachievement vary considerably across studies. Hence, comparing results and drawing general conclusions are difficult, which has severely hampered scientific progress (see Dowdall & Colangelo, 1982; Preckel, Holling, & Vock, 2006; Ziegler, Ziegler, & Stoeger, 2012).

According to Reis and McCoach (2000), definitions of underachievement can be categorized in four different ways. A first approach is to determine a quantified discrepancy between a person's potential and achievement (e.g., more than one standard deviation discrepancy between the standardized ability and achievement measures). A second category subsumes studies that speak of underachievement when a person's intellectual potential exceeds certain cut-off values (e.g.,

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http://dx.doi.org/10.1016/j.lindif.2016.08.006
1041-6080/

IQ ≥ 130) but school achievement falls below a defined level of achievement (e.g., grade ≤ C on US scales). The existence of a discrepancy between actual school achievement and the one predicted by a student's intellectual potential (e.g., more than one standard error of the regression) determines underachievement in the third category, the regression analytic approach (e.g., Lau & Chan, 2001; Preckel et al., 2006). In the last category, learners are called underachievers simply if they fail to take advantage of their latent intellectual potential (see Gagné, 2004, 2005).

Educational psychologists have been studying students who underachieve for approximately 70 years (e.g., Conklin, 1940; McCall, 1994; Reis & McCoach, 2000; Siegle, 2013; Thorndike, 1963). In the course of these many years, underachievement research received a great deal of criticism. In addition to the heterogeneity of definitions (e.g., Siegle, 2013; Smith, 2003; Thorndike, 1963), critics further list a number of methodological shortcomings. For instance, when cut-off values or a specific discrepancy between potential and achievement are used to define underachievement, the measurement errors inherent in any psychological assessment are neglected. Ziegler et al. (2012), who applied these operational definitions of underachievement, could exemplarily show how the number of underachievers, given a certain true number, is severely overrated due to measurement errors. Moreover, by using cut-off values or a discrepancy, the at least ordinal variables intellectual potential and achievement are used to rather arbitrarily create distinct categories of normal, high, or underachievement (Reis & McCoach, 2000). In the regression analytic approach to define underachievement, the estimation of the regression is based on the whole student sample that also encompasses the to-be-detected underachievers. Consequently, the standard error of estimation, whose magnitude is commonly used to determine underachievement, is biased because the regression itself is biased by the underachievers in the sample. To summarize, justified criticism led to a decline in studies on scholastic underachievement in recent decades. Although the construct of underachievement is definitely of substantial value, the method must be reconsidered.

To avoid the common points of criticism, we decided to apply latent profile analysis (LPA) with two indicator variables measuring intellectual potential and physics achievement to operationalize underachievement. LPA is a type of mixture model that, in simplified terms, estimates the existence of subgroups or profiles within an overall sample based on a similarity on continuous indicator variables. In the context of LPA, a systematic co-occurrence of high scores on the intellectual potential indicator variable and low scores on the physics achievement indicator variable would determine a profile of physics underachievers. Neither profile sizes nor characteristics must be defined a priori (Gibson, 1959; Lazarsfeld & Henry, 1968; Vermunt & Magidson, 2002). The analysis seeks to explain similarity on continuous indicator variables by relating the similarity to a newly introduced categorical latent variable that defines the profiles. The number of profiles that are estimated must be specified by the user. As a result, the LPA produces indicators of the quality of the respective profile solution, profile sizes and characteristics and profile membership probabilities for every person.

Using LPA, methodological problems that accompany cut-off values and a priori defined discrepancies can be circumvented. LPA allows for classification uncertainty because membership in any profile is represented as a probability. Thus, a student is not deterministically assigned to one distinct profile (e.g., an underachievers profile). Rather, variables are created indicating the profile membership probability for every profile for every student. The LPA is intended to describe the whole student sample in the form of profiles and is not geared only to the categorization of students into underachievers and non-underachievers. Therefore, the students' data are clustered based on similarities on the intellectual potential and achievement indicator variables. This characteristic also eliminates the problem of using standard errors that are potentially biased by underachievers in the sample as decision criteria to distinguish between underachievers and non-underachievers, as is done in the regression analytic approach. The operational definition by means of LPA provides a clear instruction on how to proceed and enables comparison and replication across studies.

3. Motivational correlates of physics underachievement

Academic interest and self-concept are two variables that have often been associated with both school achievement and general scholastic underachievement. To start with the former, there is broad evidence that self-concept and school achievement influence one another, presumably in the sense of reciprocal effects (see Marsh & Craven, 2006; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). A similar reciprocal relationship is assumed for interest and school achievement (see Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Köller, Baumert, & Schnabel, 2001; Schiefele, Krapp, & Winteler, 1992). Moreover, both academic interest and self-concept could be expected to be negatively related to boredom (Pekrun, Hall, Goetz, & Perry, 2014). The authors (2014) also suggest a negative reciprocal relationship between boredom and school achievement. To conclude, self-concept and interest seem to be related to school achievement both directly and indirectly.

Concerning general scholastic underachievement, Snyder and Linnenbrink-Garcia (2013) propose several motivational factors suggested by existing research on achievement-motivation that might contribute to the development of general underachievement in gifted students at consecutive developmental stages in two postulated pathways. At the third stage, which starts with entry to secondary school, the authors assume a decrease in academic self-concept due to the Big Fish Little Pond Effect (see, e.g., Marsh, 1987), leading to coping mechanisms such as disidentification with academics and disengagement. In the alternative pathway to underachievement, students in secondary school who experience enhanced academic challenge may consider the costs (such as effort and time) of academics increasingly high and therefore suffer from decreasing utility, intrinsic, and attainment value concerning academics, again leading to disengagement and disidentification. While the first pathway may be evidenced by decreased academic self-concept, the second pathway may be reflected particularly in decreased interest in academics.

In line with these considerations, literature reviews reported a poor academic self-concept as a frequently seen characteristic of general scholastic underachievers (McCall, 1994; Reis & McCoach, 2000). According to Hanses and Rost (1998), gifted underachievers showed strikingly lower scores on an academic self-concept scale in primary school than did their achieving peers. Referring to the domain of physics, top performers in science are characterized by an exceptionally high self-concept in science (Organisation for Economic Co-operation and Development, 2009). Therefore, a low self-concept in physics may accompany physics underachievement. Moreover, gifted high achievers and gifted underachievers were also found to differ concerning their interest in classes, with more-positive attitudes on the part of the high achievers (McCoach & Siegle, 2003). In the domain of physics, excellent achievement was associated with particularly high interest in physics or science in general (Adams et al., 2006; Lubinski & Benbow, 2006; Organisation for Economic Co-operation and Development, 2009; Robertson, Smeets, Lubinski, & Benbow, 2010). Consequently, low interest in physics can also be expected to accompany physics underachievement.

More motivational variables can be assumed associated with physics underachievement. However, as summarized above, the interplay between academic interest and self-concept, on the one hand, and academic achievement and underachievement, on the other hand, is evidenced by extensive research. To conclude, linking our knowledge from these fields of research to findings in the domain of physics, existing research suggests a deficit on the part of physics underachievers in terms of interest and self-concept in physics.