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Title of your paper: Can Students' Cognitive Processing Skills Moderate the Effect of Cognitive Activation on Student Learning? An Exploratory Study

Abstract Prior work has supported the importance of engaging *all* students in cognitively activating teaching to support their higher-order thinking. However, in most of the extant studies, the effect of this type of teaching on student learning has been explored on the average, without considering the moderating effect that individual students' cognitive processing skills can have on the association between cognitive activation and student learning. Bringing together two fields that have in parallel contributed to this line of inquiry—educational effectiveness and improvement research and cognitive psychology—in this study we sought to investigate whether students' cognitive processing skills as conceptualized in the *Planning, Attention, Simultaneous and Successive (PASS) processing* theory moderate the effect of cognitive activation—as conceptualized in the *Three Basic Dimension* (TBD) model—on student cognitive and affective learning. Herein, we investigated this inquiry, focusing on Algebra, given its potential in engaging students in cognitively activating work. Toward this end, we recruited 31 Grade-6 teachers and their 558 students. Students' beginning-of-year algebra performance was measured with a validated test; a validated student survey tapping into three affective aspects (likeness, anxiety, and self-efficacy) and students' background characteristics was also administered at the beginning of the year. Using the *Cognitive Assessment System-2 Brief*, individual student interviews were conducted to examine students' cognitive processing skills. We are currently using a student survey based on the *TBD* model to collect student ratings on cognitive activation for each of the three focal algebra lessons per teacher. The algebra test and the affective student survey will be administered again at the end of the year. If the use of multi-variate multi-level models empirically supports the moderating effect of student cognitive processing skills, the importance of supporting the development of students' cognitive processing skills to productively engage in cognitively activating teaching will be underlined.

Extended summary

Objective and Theoretical Perspectives

During the last two decades significant attention has been paid on ambitious teaching (Cohen, 2011), which aims at engaging all students in challenging work (Lampert et al., 2010). This type of teaching, which has been shown to promote student learning (e.g., Baumert et al., 2010; Ni et al., 2018), appears to be highly needed worldwide, especially given recent (OECD, 2019) and older (Hiebert et al., 2003) findings suggesting its rather infrequent use in different countries. Despite its importance, several open questions remain regarding its implementation, including "how to ensure that all students can access and productively engage in cognitively demanding [work]" (Tekkumru-Kisa et al., 2020, p. 613). In fact, existing studies (e.g., Kane & Staiger, 2012; Kunter et al., 2013), especially in educational effectiveness and improvement research (EEIR), have been examining the impact of cognitive activation on the average, without any systematic attempt to consider if different students might benefit differently from cognitively activating teaching.

Aiming to start addressing this issue, the current study follows an interdisciplinary approach, drawing on two fields—EEIR and cognitive psychology—which have approached it from distinct

angles. EEIR has helped unravel the effects of teaching on student learning without considering how students' cognitive processes might moderate this effect; cognitive psychology has focused on students' cognitive processes without paying much attention to teaching. Capitalizing on both fields, this study aims to examine if students' processing skills might moderate the effect of cognitive activation on student learning.

Toward this end, the study draws on the Three Basic Dimensions model (Klieme et al., 2001) and particularly cognitive activation. Prior studies have shown cognitive activation to positively relate to student learning, even when being measured by using student ratings (Praetorius et al., 2018). The study also draws on a neurocognitive theory of students' cognitive processing skills called PASS (for Planning, Attention, Simultaneous, and Successive processing) and its associated way for measuring it (Cognitive Assessment System [CAS]; Naglieri & Das, 1997; see also Naglieri et al., 2014, for its second edition). Several studies have shown significant effects of each PASS process on mathematics performance (e.g., Cai et al., 2016; Georgiou et al., 2020). Finally, responding to recent calls within EEIR to expand the scope of student outcomes explored (see Lindorff et al., 2020; Scheerens & Blömeke, 2016), the study investigates both cognitive and affective outcomes.

Research Question

This study aims to address the following question: *To what extent is the effect of cognitive activation on student learning (cognitive and affective) moderated by students' cognitive processing skills, once controlling for different student background characteristics and classroom contextual effects?*

Methodology

Setting/participants. A sample of 31 Cypriot elementary school teachers teaching mathematics to sixth-grade students and their students (N=558) participated in the study (see demographics in Table 1). We focused only on Grade 6 seeking to explore this inquiry with respect to algebra (largely taught in Gr.6 in Cyprus), which has been shown to have significant potential for cognitively activating students (Stein et al., 2011).

Data sources. We administered a beginning-of-year validated algebra test (Chimoni et al., 2018); a beginning-of-year validated student survey based on TIMSS (2011) measuring students' likeness, anxiety, and self-efficacy in mathematics; a validated survey measuring student SES and other background characteristics, including gender, ethnicity, and language spoken at home (Kyriakides et al., 2019); and a standardized battery of cognitive processing tests, yielded from the Cognitive Assessment System (CAS) -2 Brief standardized battery of tests (CAS2, Naglieri et al., 2014). Data collection is ongoing and we are currently collecting students' ratings on the level of cognitive activation experienced in each or the three lessons to be observed, using a validated student survey (Praetorius et al., 2018); the algebra test and the student affective survey are to be administered again in April/early May 2022.

Data analysis. By the time the conference will take place we will have all of our data collected and have run our planned statistical analyses. To address our research inquiry, we will employ multi-variate multi-level analyses with students nested within teachers. Student end-of-year cognitive and affective outcomes will serve as the dependent variables and (i) student background characteristics, (ii) beginning-of-year cognitive and affective outcomes, and (iii) classroom composition effects will serve as the independent variables. Once exploring for the main effect of cognitive activation on student cognitive and affective learning, we will then investigate the potential moderation effect of students' cognitive processing skills by regressing the interaction of these skills and cognitive activation on student learning.

Preliminary Findings

So far, we have obtained and analyzed the data on students' beginning-of-year algebra and affective scores, SES and other background characteristics, and CAS-2 scores. All scales have been found to have good psychometric properties. As Table 2 suggests, the psychometric properties of the scales developed for students' algebra performance and SES had satisfactory reliabilities ranging from 0.78 to 0.99, infit/outfit mean squares close to one, and infit/outfit t values close to zero. Also as shown in Figs. 1 and 2, there was a relatively good match between the item-difficulty estimates and the person-parameter estimates. The three factors (likeness, anxiety, and self-efficacy) emerging from students' affective survey were found to have high reliabilities (Cronbach's alpha= 0.89, 0.81, and 0.86, respectively). Cronbach's alpha reliabilities for the four CAS-2: Brief sub-scores were higher than 0.85 and 0.89 for the total score. Student's CAS-2: Brief total score was moderately correlated with their algebra performance (r = 0.51), suggesting that students' cognitive processing skills could function as a moderator for the effect of cognitive activation on students' algebra performance.

Discussion -Significance

If students' cognitive processing skills are found to moderate the effect of cognitive activation on student learning, this study will empirically support the need to attend to how different groups of students might differentially profit from this type of teaching. Interventions that gear toward improving students' processing skills (e.g., Iseman & Naglieri, 2011) can then be considered, especially given prior findings suggesting these cognitive processing skills to be teachable and learnable (Naglieri & Johnson, 2000).

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Table 1

Students	Frequency	Percent
Girls	270	48.4
Immigrant background	80	14.3
Language used at home – only Greek	493	88.4
Language used at home – other than Greek	65	11.6
Language used at home – Both Greek and other language	15	2.7
Teachers		
Female teacher	19	61.3
Teaching experience (0-10 years)	0	0.0
Teaching experience (11 – 15 years)	3	9.7
Teaching experience (16 – 20 years)	8	25.8
Teaching experience (21 or more years)	20	64.5

Number of participants (Students N=558, Teachers N=31)

Table 2
Item and student parameter estimates (Algebra test and SES).

Parameter estimates		**Algebra Test (n=558)**	**SES (n=558)**
Mean	(Items)	0.00	0.00
	(Students)	-0.94	0.73
SD	(Items)	1.48	2.08
	(Students)	1.67	0.93
Reliability	(Items)	0.99	0.99
	(Students)	0.93	0.82
Infit mean square	(Items)	0.99	0.99
	(Students)	1.01	0.99
Outfit mean square	(Items)	0.97	0.95
	(Students)	0.99	0.95
Infit t	(Items)	-0.14	0.06
	(Students)	0.02	-0.08
Outfit t	(Items)	-0.06	0.03
	(Students)	0.05	0.11

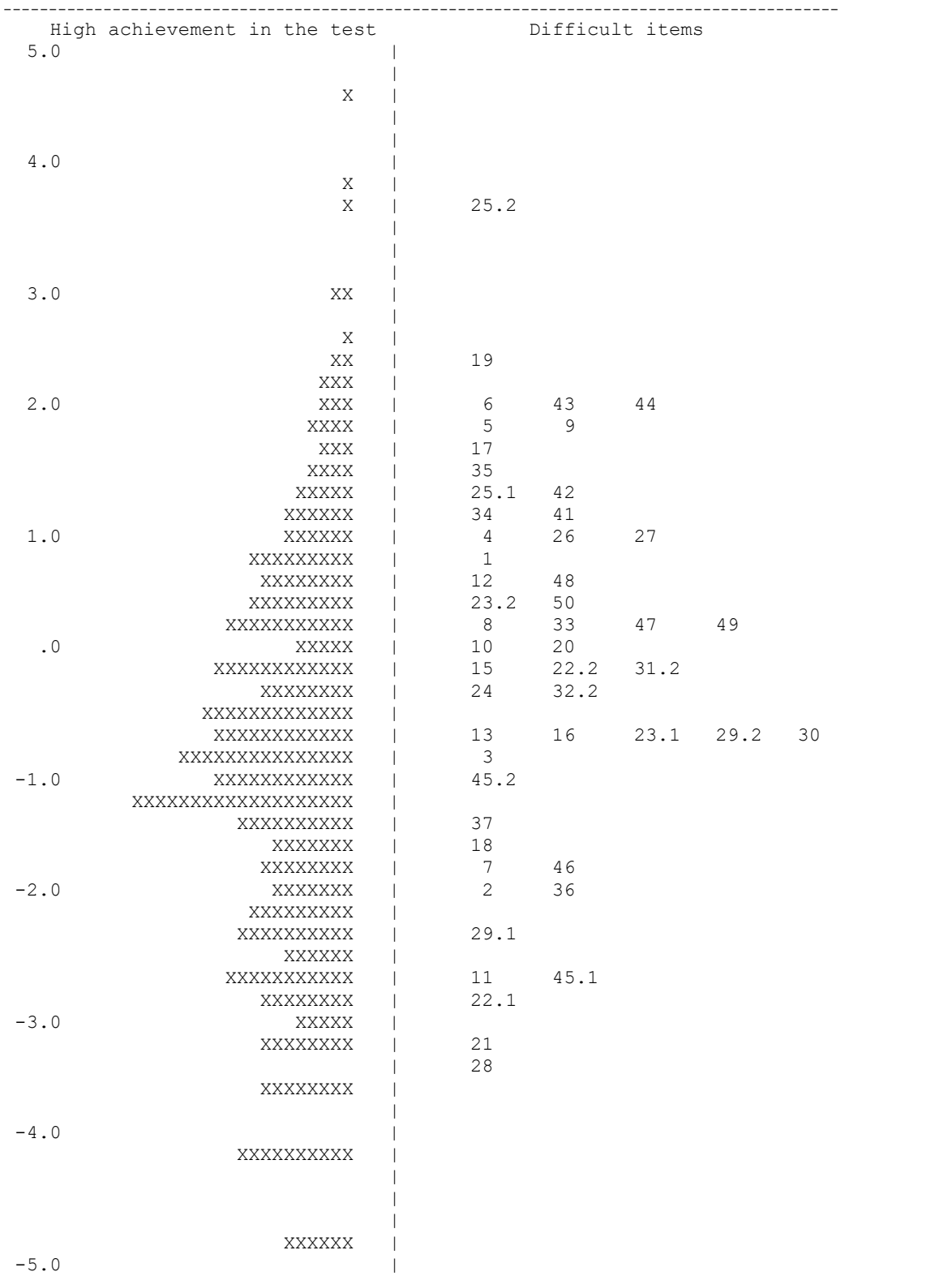

Fig. 1. The scale capturing student ability in algebra items (N=558, L=47)

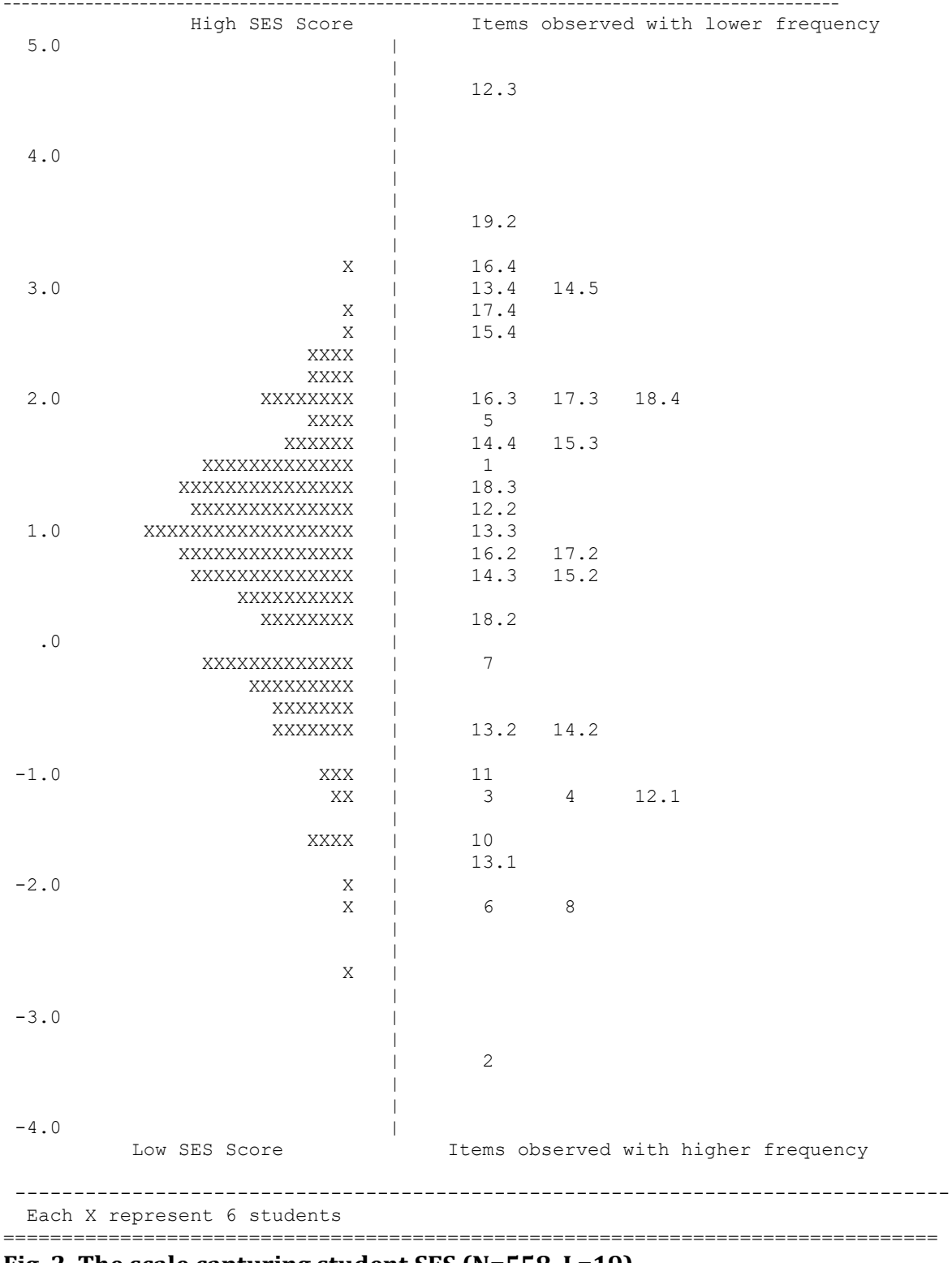

Fig. 2. The scale capturing student SES (N=558, L=19)