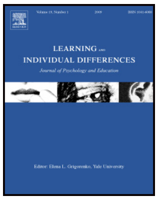
Learning and Individual Differences 52 (2016) 97–108

Contents lists available at ScienceDirect

Learning and Individual Differences

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



Cross cultural comparison of grade 6 students' performance and strategy use on graphic and non-graphic tasks

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A R T I C L E   I N F O

Article history:
Received 13 October 2015
Received in revised form 25 August 2016
Accepted 14 October 2016
Available online xxxx

Keywords:
Mathematics
Visual reasoning
Cross-cultural comparisons
Graphic and non-graphic tasks
Strategy use

A B S T R A C T

This investigation examined Singaporean and Australian students' performance and strategy use when solving mathematics tasks. Half of the questions in the 24-item test were drawn from the national Singaporean Grade 6 test, with the other 12 items sourced from the Australian national assessment. 1187 grade 6 students solved graphic and non-graphic mathematics tasks and reported their solution strategies later classified and coded as symbolic, pictorial or imagistic. Results revealed performance differences in favor of the Singaporean cohort on three of the four task categories. There were distinct differences between the types of strategies employed by the students across these task categories. The Singaporean students were more likely to use conditioned heuristics to solve the tasks, especially the non-graphic tasks, whereas the Australian students were reluctant to use these heuristics. Cultural differences were also found in the way students solved the tasks, especially when encountering unfamiliar tasks.

1. Introduction

1.1. The role of context in mathematics assessment tasks

International assessment exercises, such as the Programme for International Student Assessment (PISA), aim to compare student performance on “universal” test items. These test items are devoid of cultural nuisances or context since task content is usually associated with the societal structures, values and practices found in the meaning of the items' context (Byrne et al., 2009). By contrast, national assessments are used to measure student progress against the national (or equivalent) curriculum. These tests are designed to indicate how well students understand the material being taught in classrooms. So it stands to reason that such test items are developed within the context of the respective country's curriculum, culture and teaching ideology. Xu and Clarke (2013) maintained that even within cultures (such as East Asian), the differing contexts within individual classrooms are influential on students' mathematics learning. In the research literature, contextuality relates to how people respond to, and reason in, different situations (e.g., DiSessa, Gillespie, & Esterly, 2004).

From a practice (classroom) perspective, mathematics instruction and task representation differ across country (and cultures). The curricula in some countries place more emphasis on multiple representations of mathematics processes while others focus on structured symbolic reasoning (Mayer, Sims, & Hidetsugu, 1995). Such cultural preferences are likely to have some influence on how students make sense of and represent mathematics assessment items. Theoretically, it has been argued that the structural representation of a given task cannot be separated from the conceptualized knowledge that is devoted to task completion (Kirsh, 2009) since the processing of information and schema activation are influenced by contextual knowledge (Sabella & Redish, 2007). The content embedded within a task—whether graphic, symbolic, textual, or combinations of these elements—influences knowledge activation (Lowrie, Diezmann & Logan, 2011). Further, Nehm and Ha (2011) maintained, “contextuality is a significant contributor to how people perceive, use, internally represent, and solve problems” (p. 239).

This investigation focused on two ideologically different mathematics curricula, as a way to ascertain the effect of contextual unfamiliarity in relation to three variables: (i) student performance, (ii) the strategy that they used to solve the problems, and (iii) the nature of the mathematical tasks (i.e., graphic and non-graphic). In order to establish contextual unfamiliarity, we sourced mathematics assessment items from countries with distinctly different pedagogical and cultural traditions. As such, the context from which an assessment item is drawn is a key feature of this study.

1.2. Teaching, learning and assessment culture in Mathematics: The Australian context

The Australian mathematics curriculum is framed around the premise that students should recognize connections between specific content strands of mathematics and other disciplines. As a consequence, the

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http://dx.doi.org/10.1016/j.lindif.2016.10.005
1041-6080/

application of mathematics knowledge and thinking is afforded considerable attention in the curriculum and related pedagogical practices. This application of mathematics knowledge and skill is known as “numeracy” (Australian Association of Mathematics Teachers, 1998). According to the Australian Curriculum (Australian Curriculum, Assessment and Reporting Authority, n.d.), numeracy is deemed a general capability which requires recognition of the role of mathematics in the world. Numeracy reflects flexibility in adapting mathematical skills and knowledge to a variety of domains and is a key component of the national teaching curriculum in Australia.

The development of the National Curriculum and the related assessments in Australia are overseen by the Australian Curriculum, Assessment and Reporting Authority (ACARA). According to the nationally implemented *foundation through to year ten Curriculum* in Mathematics: “it is important that the Mathematics curriculum provides the opportunity to apply mathematical understanding and skills in context, both in other learning areas and in real world contexts” (Australian Curriculum, Assessment and Reporting Authority, 2015). As such, pedagogical practices are likely to be established within cooperative learning situations, with mathematics tasks that have an inquiry base and the opportunity for learning through open-ended investigations. The Australian Curriculum develops concepts using concrete materials in the early years of schooling and gradually introduces formal operations and symbolic notations.

A national approach to both curriculum and assessment is relatively new to the Australian educational landscape. In 2008 a national assessment program was introduced (National Assessment Program: Literacy and Numeracy; NAPLAN) and the Australian Curriculum for Mathematics was fully implemented across all states and territories from 2014. The purpose of the numeracy test of the NAPLAN is to provide schools, teachers and parents with information regarding their students' numeracy skills to ensure students have appropriate levels of the foundational knowledge required to meet educational outcomes. The majority of students will undertake the numeracy test 4 times in their schooling life at two year intervals: grade 3, 5, 7, and 9. A high proportion of the mathematics items in the respective NAPLAN tests include a graphic—as many as 80% of items in the Grade 3 test to 60% in the Grade 9 test (Lowrie & Diezmann, 2009). Despite this being a standardized test, the testing authority (ACARA) maintains that it is not high stakes, in that the consequences of performance do not influence individual student educational outcomes. Rather, the results are predominantly used by schools and teachers to identify areas of weakness among cohorts of students and to measure trends over time within schools. The national curriculum in Australia provides a framework for pedagogical content but leaves the implementation open to teacher interpretation and allows for variability in teaching practices.

Although Australian students do not perform as highly as Singaporean students on international comparisons, their mathematics self-concept is higher (Lee, 2009). It seems to be the case that the Australian students are less anxious about their national tests than Singaporean students.

1.3. Teaching, learning and assessment culture in Mathematics: the Singapore context

The Singapore education system is embedded within a Confucian culture associated with high academic achievement and task persistence (Stankov, 2010). Confucian heritage countries (such as Singapore) consistently produce outstanding results in standardized international mathematics assessment (Thomson, De Bortoli, & Buckley, 2012; Lowrie & Logan, 2015; Cvencek, Kapur, & Meltzoff, 2015). Teachers tend to promote and value specific strategies that equip students to be successful across a range of tasks and especially in assessment situations. The Singapore curriculum is more differentiated than the Australian curriculum, which tends to provide more focused on experiences in mathematics (Dindyal, 2006). Indeed, Singapore has structured its mathematics program around problem solving with the explicit teaching of processes and heuristics highly prominent (Ho & Hedberg, 2005). Problem solving is at the core of the curriculum framework, with the explicit teaching of heuristics encouraged (Ho & Lowrie, 2014). The heuristics approach to mathematical problem solving was outlined by Pólya (1957). Contrary to the standard psychological definition of heuristics which tends to refer to “rules of thumb” (Goldstein, 2005), the heuristics approach taught in Singapore is a principled approach to mathematical problem solving. The four principles described by Pólya provide a framework for problem solvers to understand a problem, devise a plan, implement a solution and then review or adapt their approach.

In Singapore, curriculum-based learning experiences are much more regulatory than in Australia, where teachers generally interpret the curriculum. For example, Singaporean curriculum materials such as textbooks must be based on the framework, with independent companies requiring formal approval from the Ministry of Education before being introduced in schools (Dindyal, 2006). The textbooks foster deep understanding of mathematics concepts through multi-step problems that utilize specific heuristics. Teachers typically focus on the mastery of specific procedures and classroom discussion is predominantly teacher dominated and lacks extended discussion of concepts of problem representation (Hogan, 2014).

From an assessment perspective, the central purpose of the Primary School Leaving Examination (PSLE) is to place students into graded (selected) high school classes and schools, and is considered to be very high stakes (Lim & Tan, 1999). Many students attend extra classes before sitting the PSLE, and teachers feel compelled to prepare students well for this test, such is its impact on individual student's high school opportunities. The PSLE has a significantly higher proportion of word problems in the tests than Australia's NAPLAN (Greenlees, 2013).

1.4. Internal and external representations

The role and nature of representation in problem solving has been investigated widely in the cognitive psychology and mathematics education literature (Borst, Ganis, Thompson, & Kosslyn, 2012; Goldin, 2002). Within this literature, representation is generally defined as the symbols and images used to make sense of a mathematical situation (Goldin & Shteingold, 2001). Representations are classified within two systems, namely *internal* and *external*. Internal representations are commonly classified as pictures “in the mind's eye” (Kosslyn, 1983) and include various forms of concrete and dynamic imagery (Presmeg, 1986) associated with personalized, and often idiosyncratic, ideas, constructs and images. External representations include conventional symbolic systems of mathematics (such as algebraic notation or number lines), graphical representations (e.g., graphs and maps) and schematic representations (e.g., networks). These two systems do not exist as separate entities and are seen as “a two-sided process, an interaction of internalization of external representations and externalization of mental images” (Pape & Tchoshanov, 2001, p. 119). In an elementary mathematics classroom, visual-spatial information is commonly represented schematically or pictorially (Hegarty & Kozhevnikov, 1999) while verbal information is represented with number sentences or algorithms (Lowrie & Clements, 2001; Lowrie & Kay, 2001).

The manner in which individuals internally represent or process information is often framed within the psychological construct of cognitive style (Kozhevnikov, Kosslyn, & Shephard, 2005). A number of influential studies in the last 40 years were based on the premise that students *prefer* to either solve tasks in a visual (imagery-based) or analytic (non-visual or verbal) manner (Krutetskii, 1976; Lean & Clements, 1981; Presmeg, 1986). These studies placed students on a continuum, analyzing student performance with respect to how they organized and processed information. To some degree these views remain. Although the capacity to construct an appropriate internal representation influences problem-solving performance (e.g., Hegarty & Kozhevnikov, 1999; Schoenfeld, 2002), the visualizer-verbalizer continuum has