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Lost in Memorization: The Case of Science Instruction in KSA Schools and the Argument for a Promotion of Science Literacy Based on Formative Assessment Practices

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Abstract
This study focuses on the connection between teachers' assessment and students' achievement in science instruction in schools of the Kingdom of Saudi Arabia (KSA). Specifically, data from TIMMS 2011 were analyzed to answer the question "What is the effect of KSA teacher assessment practices on grade 8 students' achievement in science?" Data were selected for their relevance to the question, including those on approaches to science-instruction as perceived by teachers themselves, data were analyzed with regard to standards set by international discourse, compared with the international average, and were internally weighted to maintain coherent patterns. Findings show a relation between the knowledge-focused approach to teaching and assessing students' achievement prevalent in KSA science instruction and the low achievement results of KSA students in TIMMS 2011. A look at assessment practices in KSA science instruction is called for: There should be a correlation between the extent to which continuous, formative assessment is practiced during instruction and students' achievement as stated by international studies. In our secondary analysis of TIMMS results, we found no traces of an application of formative assessment and indeed no clues as to whether the very concept is known to teachers at all. Professional development about formative assessment and more emphasis on the procedural side of science in KSA instruction are recommended.

Keywords: assessment practices, KSA schools, science achievement, TIMSS 2011.

INTRODUCTION

The two concepts of scientific literacy and formative assessment are basic to an understanding of recent discourse about science education. Both are elements of key significance, because both are features of a fundamental conceptual change in this field of study, and both inform the the test-setup of international questionnaires such as TIMSS. By providing brief sketches (A, B), we offer our perception of these terms.
The specific situation of science instruction in schools of the KSA needs to be described, and particular challenges pointed out (C). However, the reform processes' main structural features are similar to education reform processes anywhere. Thus, tools and approaches applicable in this case might well be indicative of wider use and more general applicability.

Science Literacy: Process Transcends Knowledge

TIMSS is designed to reward students‘ investigative competence. TIMSS comment on “Teacher Emphasis on Science Investigation “explains this rationale's compatibility with research (p. 406):

As noted in the TIMSS 2011 Science Assessment Framework, one of the ways in which students have been encouraged to build upon their knowledge and understanding of science is through the process of scientific inquiry, and, as documented in the TIMSS 2011 Encyclopedia, the contemporary science curricula of many countries place considerable emphasis on engaging students in this process. For example, the most recent recommendations for effective instructional practices of the US National Research Council (NRC) include an emphasis on inquiry activities (NRC, 1996; NRC, 2001; NRC, 2013). A recent meta-analysis across 138 studies indicated that using some level of inquiry based instruction had a positive relationship with student understanding and retention of science content. In particular, instruction emphasizing active thinking and drawing conclusions from data or providing hands-on experience with scientific phenomena were associated with increased likelihood of scientific understanding.” (AAAS, 2012)

The comment indicates an accord of TIMSS philosophy on science instruction with actual developments in research-based discourse. During the last few decades, research-based discourse has definitely favored instruction centered on the "processes" of science, promoting an understanding of the methodology of scientific investigation (instead of memorizing data and definitions, as in the content-centered approach that used to be the common standard of science instruction in most countries, and appears to be the only one used in KSA schools).

The new paradigm of science instruction is named scientific literacy" (AAAS, 1998; National Science Education Standards 1996) or "science literacy". It informs both the science-sections of TIMSS and the OECD's PISA (Programme for International Student Assessment).

Formative Assessment Superior to Summative Assessment

There is a close link between teaching and assessment practices (Gullickson, 1985; Phye 1997). According to the National Research Council (2001), the connection between teaching and assessment is so close that "it is at times difficult to separate the two." It follows that "the quickest way to change student learning is to change the assessment system" (Elton and Laurillard, 1979, p. 100).

The term "summative assessment" refers to the application of tests and exams as instruments to judge students' achievement in terms of a score that measures attainment of a number of objectives (Crossouard, 2011). As was pointed out by critics early on, this approach does not necessarily reveal a student's total knowledge, nor what was truly learned of a subject (Satterly, 1989). Moreover, the approach contributes to a transformation of the aim of schooling itself, which changes from learning to performing well in examinations (Harlen, 2012). At the same time, the practice to judge learning progress based on tests might negatively impact on students' self confidence (Harlen, 2012).

According to Chappuis and Stiggins (2006), low achieving students benefit from formative assessment procedures that will help them to express themselves and thus might lead them out of the cycle of low self-esteem re-enforced by failed tests. However, positive effects are not limited to low achievers: Self-motivation, self-confidence, and self-reliance are nurtured among all students (Wilhelm, 2012).

At the same time, there is a prospective effect of formative assessment that counteracts negative side effects of the exclusive use of summative assessment by preventing the domination of learning for tests and examinations. (In some instances, "formative" is used interchangeably with "continuous assessment" (Anand, 2012), and in one sample of curriculum construction, "formative" is put in contrast as "authentic assessment" with "traditional techniques" (Hodges & Harrell, 2005).

Benefits of diagnostic and interactive uses of evaluative instruments for the improvement of learning processes - the practice of formative assessment - are emphasized by a meta-analysis of more than 250 studies comparing formative (ongoing interaction between teacher and students) vs. summative assessment strategies: formative assessment is shown to have the more powerful effect on student learning throughout all subjects at all grade levels (Black and Wiliam, 1998). The same authors point to the approach's potentials for providing high quality learning, a decade later (2009); they give a broad definition of formative assessment as *"all those activities undertaken by teachers and/or students which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged."* Such an approach will - planfully implemented and including thorough feedback and clearly defined learning targets - according to their prediction, bring about a reduction of the amount of time spent by students for learning.

Recently, formative assessment's superiority as diagnostic tool is emphasized. The approach facilitates identification of students' misconceptions and degree of understanding (Rosas, 2014). Accordingly, assessment practice that lacks formative elements (by exclusively focussing on tests and exams) has little means to identify specific deficiencies and might lead to misrepresentation of students' learning (Tridane, Belaaouad, Benmokhtar, Gourja and Radid, 2015).

For an explanation of the approach's positive effects, the close relationship between supportive feedback (as core element of formative assessment) and principles of education is pointed to (Boston, 2002; Lee, Harrison and Black, 2010; McMillan, 2001). One argument points out that the feedback provided by formative assessment reflects the actual state of performance and thus invites utilization to stimulate learning (Timmers, Walraven, and Veldkamp, 2015). One study reasons that constant feeedback - a typical feature of formative assessment - provides students with a scaffolding for their learning, and that this involves them as partners in the assessment process (Fluckiger, Vigil. Pasco and Danielson, 2010). The line of psychologic reasoning is

followed through in an analysis of the relationship between *scaffolding* and *zone of proximate development*, Vygotsky's term (Heritage, 2010). The argument states that through formative assessment a zone of proximate development is established for co-operation between teachers and students; this in turn forms a medium, as Heritage elaborates, in which the *more expert other* (the teacher) supports growth and learning by interaction.

A distinctive set of techniques and tools has been developed and is used for formative assessment, including journals, checklists, portfolios and presentations. These tools are applicable for science instruction; there is a special relation to the field of science literacy, because just as science instruction moves away from memorizing formula to promoting investigative competence, assessment practices changes by inclusion of presentative, interactive, continuous elements.

Science Instruction in the KSA School System

The Kingdom of Saudi Arabia provides free access to primary (six years), intermediate (three years), and secondary education (three years) which is controlled centrally by the Ministry of Education (MoE). Boys and girls attend separate schools.

The school year is divided into two semesters. In grades 7 through 12, assessment is emphasized to a remarkable degree: In each of the two semesters, 15 weeks are given to instruction, followed by two weeks devoted exclusively to final examinations; in grades 1 through 6, final exams are replaced by continuous assessment from teachers (MoE, 2006).

Science is taught as a general topic in all primary and intermediate grades (1 to 9). In intermediate grades (7 to 9), the timetable provides 4 hours per week for science instruction. Starting from secondary school (grade 10), the subject of General Science is broken down into subjects Physics, Chemistry, and Biology. In final grades 11 and 12, students who choose to study the scientific track select from these three course options in addition to Geology (Alsslloom, 1991).

In spite of a frame that secures science instruction's position and importance, achievement of KSA schools by international comparison is beneath average. In 2011, KSA schools participated in the TIMSS (TIMSS 2011- see report by Martin, Mullis, Foy, & Stanco, 2012), an international comparative assessment that is conducted by the International Association for the Evaluation of Educational Achievement (IEA), and is designed not only to measure and compare achievement but also to contribute to the improvement of teaching and learning in mathematics and science through evidence-based findings.

Science achievement of grade 8 students on the Results-Table (TIMSS report, p. 40) puts KSA schools at rank 31 among 42 participating countries (ranging from highest ranking Singapore with an average scale score of 590 to lowest ranking Ghana with a score averaging 306). KSA at position 31 holds an average scale score of 436, which is 13 rank-places beneath the average achievement, the TIMSS scale centerpoint of 500 score.

It is remarkable that the comparatively low achievement - and, indeed, the lack of improvement - should come even after a determined effort by the Kingdom's MoE to overhaul science instruction. Currently (since 2009), K-12 science and mathematics education in Saudi Arabia go through a reform process that aims at improving the quality of education and to raise the level of achievement. The initiative was launched in 2009; a western (McGraw-Hill) science textbook-series was adopted to all school levels. These textbooks support the development of inquiry-based learning, scientific literacy, and favor formative assessment techniques (Alshaya & Abdulhameed, 2011).

As for reaction to these innovative efforts among the teaching force, available research indicates a pattern of reluctance that is not uncommon in similar instances:

Alzaghibi and Bin Salamah (2011) indicate teachers general dissatisfaction with the project.

Aldahmash & Alshamrani (2012) find that science teachers are still using in practice the same traditional methods of teaching and assessing science that they have used before 2009 (and the attempt at innovation). Al-Sadan (2000) notices that teachers still favor written examinations over techniques available in a formative-assessment toolbox.

Surmising that no systematic use is made of formative assessment in KSA schools, leaving its potential for changing science instruction to promote scientific literacy untapped, we envision an approach to innovative science education that utilizes a change of assessment practice as key element. Hypothesizing that the current neglect is linked to ignorance of the very concept of formative assessment among teachers, we use TIMSS 2011 results for a secondary analysis to determine actual assessment practice and to identify specifics of the area for improvement.

Statement of the Problem

Science instruction in schools of the Kingdom of Saudi Arabia (KSA) has shown little progress over the past few decades. By international comparison (Trends in International Mathematics and Science Study - TIMMS - and Program for International Student Assessment - PISA -), KSA students continue to be ranked among the lower achieving. Attempting to change the predominant pattern of instruction that still is characterized by having students memorize terms and phrases, the Ministry of Education has used different approaches, culminating with the introduction of a new science textbook series in KSA schools in 2009. These textbooks are an adaptation of the American McGraw-Hill series that promotes a science literacy approach.

However, TIMSS 2011 puts KSA schools at rank 31 among 42 participating countries, 13 rank-places beneath average achievement (TIMMS scale center point of 500 score), showing no improvement over previous results.

Educational discourse on science instruction stresses two aspects, science literacy and formative assessment. Since the textbook series is arranged to promote science literacy (which failed to leave a mark of success on TIMMS 2011), this study aimed to find a correlation between the extent to which continuous, formative assessment is practiced during instruction and students' achievement as stated by international studies by conducting secondary analysis of TIMMS results.

Research Focus

Asking what one may learn about assessment as currently practiced in science instruction of KSA schools, we use data from TIMSS 2011 for a secondary analysis (an analysis to answer questions that were not asked in the primary analysis provided by Martin et al. 2012 for the TIMSS report). The following questions are at the centre of our research interest:

- Are there any data to indicate use of formative assessment practice?
- Which data suggest that written tests and exams might have been supplemented by continuous, formative assessment techniques?

This focus was specified into a set of four questions to investigate TIMMS data:

1. Is there sufficient time provided for science instruction?
2. What specific details emerge about science teachers assessment practice?
3. Are teachers familiar with the concept of formative assessment?
4. What obstacles in science instruction prevent formative assessment?

Procedure

TIMSS, conducted on an international scale since its instigation in 1995 every four years, claims as its main purpose - according to principles - assessment of the teaching and learning quality in mathematics and science among 4 and 8 grade students across participating countries. The exercise is meant to provide decision makers in education with reliable and timely data as a tool for enhancement of education outcomes in participating countries - by using data for making informed decisions. (Martin, et. al., 2003).

Along this line of reasoning, we selected from among the host of data provided in the TIMSS report those dealing with results, instructional time, assessment procedures and the process of instruction, grouping them in correspondence to the 4 leading questions of our research focus, in order to analyse the situation.

The TIMSS 2011 included a questionnaire for teachers, students and principals with 29 questions that covered a variety of information on background; some of these questions, focusing on assessment practices, were also included in the analysis.

The sample of this study consisted of all grade 8 science teachers who participated in TIMSS 2011 in the Kingdom of Saudi Arabia. The KSA sample comprises 153 schools with 164 teachers and 4,344 students in grade 8.

Limitation of the Study

This study aimed to find a correlation between the extents to which continuous, formative assessment is practiced during instruction and students' achievement as stated by international studies by conducting secondary analysis of TIMMS results and not using other sources of data such as classroom observations, teachers' interviews or students' interviews to explore this relationship might affect study results.

RESULTS

Results are grouped in order with research questions. Data from the TIMSS report are cited and interpreted, in accord with the four guiding questions.

1. Is there sufficient time provided for science instruction?

A look at time provided to science instruction at KSA schools compared to international average clarifies if there exists an obstacle that might well be conceived as the most obvious one. The report shows (p. 352, exhibit 8.7) that total instruction in KSA schools is 1050 hours

per year (i.a. 1031), and science instruction is 124 hours per year (i.a. 158): Compared to international average, KSA schools allow more time (19 hours) for total instruction, and less (34 hours) for science instruction. While proportions of these differences for total instruction seem well within standard range, the relation of 34 hours less than average of science is disproportionately high.

What specific details emerge about science teachers' assessment practice?

Data from three areas were analyzed:
Extent and orientation of classroom tests,
extent and use of homework for assessment,
other sources used by teachers to monitor student progress.

Classroom Assessment (Testing)

Data (report, p.424, Exhibit 8.32) shows a higher frequency of written classroom tests - a typical form of summative assessment - in KSA schools than on international average. (56 percent of KSA students are tested every two weeks, while international average is only 35 percent.) Thus, more science tests are administered over time in KSA schools than elsewhere.

These tests emphasize the knowledge component, with comparatively little weight on development of hypotheses and design of investigations ("always": KSA 13, international average 21) and questions requiring explanations or justifications ("always": KSA 29, international average 54). There are fewer questions being asked in KSA tests about the development of hypotheses and the explanation and justification than on average elsewhere.

Homework

Data about the time students claim to spend on science homework per week (report p. 419, Exhibit 8.31) shows that KSA students spend far less time on homework than their counterparts elsewhere do on average (international average in brackets).
3 hours or more: 3 % (5)
less than 3 hrs., more than 45 minutes: 14 % (29)
less than 45 minutes: 83 % (67)

According to answers to the teachers' questionnaire, teachers monitor and correct homework assignments ("always": 84 %, "sometimes": 16 %, "never": 0), and sometimes discuss homework assignments in class (79%, 18%, 3%), but are reluctant to have students correct their own homework (27%, 52%, 21%). Yet, a majority uses homework for grading students (62%, 35%, 3%)

Other Sources for Assessment

Other than classroom testing and national or regional achievement tests, teachers claim to base student assessment mainly on ongoing performance. Thus, 70 percent put major emphasis on "Evaluation of ongoing work of students" ("some emphasis": 29, "little or no emphasis": 1), more than on "classroom tests" (62, 37, 2) and on "national or regional achievement tests" (37, 42, 21).

Unfortunately, there is no definition in behavioristic terms of what "evaluation of ongoing work of students" means. At least, an inclusion of formative assessment practice appears possible, at least in principle. (While this might appear unreasonable in light of the other data, there still is a route of access that could be used to change assessment practice.)

Are Teachers Familiar with the Formative Assessment Concept?

One of TIMSS data mentions "Science Assessment" specifically ("Teacher Participation in Professional Development in Science in the Past Two Years" from the Questionnaire for Teachers, report p. 304, Exhibit 7.8).

According to their own testimony, KSA teachers participated in professional development courses for a variety of aspects of Science Instruction during the two years prior to 2011. (Figures refer to number of courses, with international average numbers in brackets.)
Science Content 56 (Intl. Ave. 55)
Science Pedagogy Instruction 65 (Intl. Ave. 58)
Science Curriculum 60 (Intl. Ave. 53)
IT into Science 41 (Intl. Ave. 49)
Improving Critical Thinking Skills 38 (Intl. Ave. 43)
Science Assessment 35 (Intl. Ave. 48)

Compared to international average, KSA teachers have participated in more professional development activities for the first three categories, while lagging behind for the second part of topics, "IT into Science", "Improving Critical Thinking Skills" and "Science Assessment".

The widest gap is in "Science Assessment" - 13 points difference. The result reinforces the suspicion of a lack of familiarity with the concept of formative assessment.

What Obstacles in Science Instruction Prevent Formative Assessment?

Extent of the Knowledge Component's Predomination

A look at achievement in Science Cognitive Domain (report p. 152, Exhibit 3.4) reveals an uneven distribution of categories. With an overall Science average score of 436, KSA students achieved different

results in the three categories of Knowing, Applying and Reasoning, indicative of an emphasis on "Knowing", score 448 (11 score points above the average), and less emphasis on "Applying", score 432 (4 score points beneath average), and almost a neglect of "Reasoning", score 424 (13 points under the average score).

The knowledge component is given more attention in KSA schools, the application component slightly less, and the reason component much less attention than on international average, revealing a knowledge-bias of instruction that might function as a structural impediment to formative assessment practice.

Use of Resources: Basis or Supplement for Instruction?

Looking at resources used by teachers for teaching science (report p. 402, Exhibit 8.26) reveals an interesting aspect, when the difference between supplementary and basic use of resources is put into focus. (A resource such as a textbook may be used as the main source of instruction, or it may just provide additional support among a number of different teaching and learning tools.) The distinction between use as basis for and as supplement to instruction is part ot the TIMSS design.

Textbooks are used as basis for instruction by 91 percent of KSA teachers (international average - i.a. - 74) and as a supplement by 7 percent (i.a. 24 workbooks and worksheets as base in KSA 46 percent (i.a. 35), as supplement 50 (i.a. 60); science equipment and materials as base in KSA 65 percent (i.a. 43), as supplement 30 (i.a. 54); computer software as base in KSA 42 percent (i.a. 16), as supplement 45 (i.a. 61).

Altogether, the extent of use as the very foundation of instruction is much higher in KSA schools than for international average, and the supplementary use - using resources as an add-on in addition to other resources - is much lower in KSA than average.

Source-domination of instruction seems to point to a specific perception of the teacher's role as agent of the coursework that is set down in the material, following the sequences that come with textbooks and other resources (rather than as director of a process of instruction, who makes use of a variety of resources that he or she deems fit for learning). Since the use of logbooks, presentations and other methods typical to the formative assessment approach require a measure of independance from the strict sequences as laid down by textbooks and other resources, the dominance of resource use as leading agents for instruction functions as an impediment to formative assessment practice.

DISCUSSION OF RESULTS

Not Enough Time for Science

The syllabus of KSA schools devotes 34 hours per year less time to science instruction than provided by schools on international average. The lag is even wider when considering total time for instruction, which is in the KSA 19 hours more than average.

While there is one country achieving much better results than KSA schools (in TIMSS 2011) with even smaller portions of the timetable devoted to teaching science (Sweden 969/94 scoring 533), this is an exception to the general pattern that shows a correspondence between time spent for instruction and achievement level in tests. (An explanation for this exception should take into account the presence of science literacy elements throughout the curriculum.)

Assessment Practice Predominated By Tests Testing Content Knowledge

Students are tested more often in KSA science classes than elsewhere, and with more emphasis on the knowledge component than the international average, with less time given to hypothesizing, explaining and justifying, for reasoning, and for designing science investigations.

In KSA schools, the knowledge component delivers the highest achievement, higher than international average, the application component achieves slightly less, and the reason component much less success than average.

With testing biased towards knowledge, the comparatively higher achievement levels in this field contrast with low achievement levels in the “applying” and, especially, “reasoning” components. However, one might ask somewhat rhetorically, how should it be possible to practice investigative methods in science instruction while testing the same students for knowledge in a way that neglects investigation and emphasizes memorized knowledge?

International science instruction, promoted by the concept of "scientific literacy", develops over time to put more emphasis on components of critical thinking such as hypothesizing, explaining, and designing investigations. At the same time, knowledge orientation with its reliance on meomorization of data, definitions and formula will be reduced to secondary importance.

The lack of tasks linked to science investigation (hypothesis justification, explanation) dovetails with

other data in KSA testing. A study by Al-Sadan from 2000 reaches a rather sceptical conclusion as to the chances of introducing other ways for assessment due to teachers‘ traditional inclination to give formal tests that are linked to textbooks and thus emphasize knowledge. Al-Sadan notices that teachers favor written examinations as one of the elements they claim to be part of "continuous assessment". Since examinations are based on the contents of the books used, students tend to focus on these and thus are deprived of the potential benefits of wider readings on subjects studied, or extra general education. As long as these patterns prevail, Al-Sadan argues, assessment will not be conducive to encourage the kind of work that enhances students' way of thinking promotes their problem solving capacities.

Data also shows what might appear as a contradiction between the high frequency of testing in KSA schools (every two weeks) and the low rate of homework for students (less than 45 minutes per week). Homework in science instruction is often a preparation for tests, when discussions of homework results in class are used for clarification of concepts and understanding of questions. With curiously little amount of homework (below international average), such preparatory use of homework appears for practical purposes precluded.

Teachers Widely Ignorant of the Formative Assessment's Concept and Practice

While participation in professional development courses is on a par with international average in the fields of science content, instruction and curriculum, in the areas of IT, Critical Thinking Skills and Assessment it is lagging behind, most dramatically in Science Assessment with only 35 courses in contrast to the international average of 48.

Thus, it might well be argued that there is a lack of information due to the lack of professional development in this field. The gap at least reveals an area for improvement, pointing to what is clearly a deficit in KSA teachers‘ education (Alshannag, Tairab, Dodeen & Abdel Fattah, 2013), as well as mathematic teachers‘ education (Dodeen, Abdelfattah, Shumrani & Abu Hilal, 2012).

As Al-bursan and Tighezza (2013) have pointed out, there is a correlation between teaching practice, professional development and student achievement. This concept brings to light another disadvantage of KSA science instruction: A possibly widespread ignorance of subject knowledge among science teachers, since in KSA schools, subject area certification is not a requirement for teachers; they are allowed to join the profession with no studies of the discipline they are going to teach beyond what they have learned when they were students at school.

At the same time, a positive effect of enhanced teacher qualification on student achievement is well demonstrated (e.g., Betts, Zau & Rice, 2003; Carr, 2006; Cavalluzzo, 2004). A type of certification that requires continuous courses to update content knowledge and teaching methods, including assessment techniques is a good predictor for improved student performance, as demonstrated by (Carr, 2006; Cavalluzzo, 2004; Darling-Hammond, 2000; Goe, 2007; and Goe & Stickler, 2008).

Obstacles to Formative Assessment: The Knowledge Component Predominates Instruction, Resources Used As Directives Not As Tools for Supplementing Instruction

TIMSS results show relative success for KSA students in the knowledge category, with far less in the application and reasoning categories, thus mirroring the respective attention provided to these categories/areas in KSA science instruction. The knowledge-bias of instruction arguably functions as structural impediment to formative assessment practice.

To illustrate this point: Since students' reasoning skills are enhanced by formative assessment methods such as presentations and exhibitions, the shortcoming of the reasoning component indicates the lack of practice which is connected to the predominance of memorization of knowledge content. This pattern is reinforced by findings about the predominant assessment practice (Results "2. Assessment practice predominated by tests testing content knowledge", above).

Furthermore, this finding is supported by an analysis of the main use made of resources. Teaching resources are used as bases for instruction, such as textbooks that provide the frame and the details of a course in science. There is comparatively little use of teaching resources as supplements, in stark contrast to the use of these elsewhere. KSA teachers tend to use resources as bases for instruction, while a majority of higher achieving countries tend to a supplementary use. Obviously, sources are understood by KSA teachers as directives to learning, not as material aids for a process of instruction directed by the teacher. And again, given the dominance of textbooks in this context, the knowledge component marginalizes other components of science education such as application and reasoning. It is the knowledge-oriented culture of instruction with its emphasis on memorization that appears as main obstacle to an application of the formative assessment approach.

CONCLUSION

The KSA students‘ comparatively low rank of achievement among participating nations is the effect of an assessment practice in KSA schools that focuses on the knowledge component with its emphasis on memorization, neglecting application and reasoning components with their emphasis on critical and creative thinking.

Science instruction in KSA schools is predominantly knowledge-oriented. TIMSS data of 2011 shows that the attempt to introduce a scientific literacy approach in 2009 (via adaptation of the McGraw-Hill textbook series devoted to science literacy) has had little impact on the predominant pattern of teaching science as a set of statements about knowledge to be learned (memorized). A mutual re-enforcement between the kind of knowledge taught and the kind of assessment practiced has established what might be called a culture of rote learning: Instruction focusing on the very terms, formula, phrases and names that tests and exams are asking students to reproduce. This cycle cannot be broken by the attempt to introduce scientific literacy through schoolbooks alone. As far as reasoning skills are representative to scientific literacy, a mode of assessment is necessary that facilitates the application and exercise of just this competence: a formative assessment approach. In order to overcome the hurdle of the culture of traditional teaching and learning that dominates science in instruction in KSA schools, the introduction of formative assessment elements appears as the most promising therapy.

While the interactive medium of a *zone of proximate development* (according to the description of formative assessment that uses Vygotsky‘s term by Heritage, 2010) might well promote the development of critical and creative thinking skills among students, our data support the impression that teachers are unfamiliar with the very concept of formative assessment, and ignorant of the wealth of instruments and techniques made available by its implementation.

A change of teachers‘ mentality may not be sufficient to bring about a change in the culture of instruction and its key element, a change in the culture of assessment: Teachers are participants in a school system that tends to evaluate them in summative fashion, according to portions of curriculum covered, and in relation to their students‘ test results. Consequently, there is pressure on teachers to confirm to these expectations and deliver by teaching to the test (Brady, 2013; Mercer, 2007; Snyder & Snyder, 2008; Williams, Stanisstreet, Spall, Boyles & Dickson, 2003). In order to introduce the concept of “formative assessment” to schools, teachers need to be provided the space and the time to adopt the approach and to develop - through intensive exchange - an adaptation that suits the KSA school system‘s specific needs and wants.

One final observation: There is less time given to science instruction in KSA school timetables than elsewhere. Arguably, the simple act of increasing time for science in schools might help improve KSA students science achievement.

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