THE DOUBLE-PAN BALANCE APPROACH: A DUPLICATE KEY TO UNDERSTAND THE MODEL OF EDUCATIONAL RECONSTRUCTION IN TERTIARY EDUCATION

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ABSTRACT

Many conceptual change approaches adapted to teaching have in the few years consolidated understanding of content-oriented curricula in tertiary education. The "Double-Pan Balance Approach" (DPBA) was used to explain the Model of Educational Reconstruction (MER) to two (2) faculty members (FM) of the University of Education, Winneba-Ghana. A comparison of the MER and DPBA models generated similarities with direct applications between the two designs. The faculty members conceptualised the MER as a double-pan balance in the first setting, analysing scientists` subject matter and that of the students on a different but equally pivoted weighing pans. The internal lever structures of the double-pan balance were equated to the learning environments as evaluated by the MER. The new way of superimposing and duplicating the MER with the DPBA has regenerated the understanding that some conceptual change designs are conceptualised as simple operationalised laboratory equipment.

Keywords: Conceptual change, content-orientation, double-pan, duplicating, lever.

HISTORY AND OVERVIEW OF THE DOUBLE-PAN BALANCE (DPA)

The Double-Pan Balance was originated and invented by the French mathematician Gilles Personne de Roberval between the years 1602 and 1675. The standard laboratory DPB has a Roberval mechanism that keeps the pans level as they move up and down. This prevents the pans from tilting as they move up and down. The principle ensures that the position of weights on the pans has no effect on the balance.

The mechanism of the scale is such that it has two identical horizontal beams, attached to each other, one is directly above the other, and supported by a vertical stable base column. The horizontal beams are joined to a vertical beam on each side of the balance with six attachment points as pivots. For easy weighing, two horizontal plates are mounted on top of the two vertical beams. This illustration is portrayed in Figure 1 below.

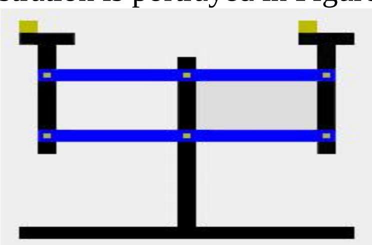

Figure 1: A double-pan balance with a Roberval mechanism linkage in Wikipedia.org/wiki/Roberval_balance

A pointer (center arrow) on the lower horizontal beam and a mark on the vertical column have been incorporated to aid in leveling the scale. In a practical session, the sample to be weighed is placed on one plate 1 (on the left), and calibrated masses are added to and subtracted from the other plate 2 (on the right) until the pointer indicates a level. The mass of the sample is then assumed to be equal to the mass of the calibrated masses - regardless of the positions of the samples on both plates. This is attributed to the vertical and horizontal beams being virtually perpendicular to each other as illustrated in Figure 2.

Figure 2: A laboratory double-pan balance with hidden Roberval mechanism linkage

As we see in Figure 2, the Double-Pan Balance (DPB) has for over decades, been very popular for measuring convenient and moderate accurate solid chemical samples in Ghanaian university laboratories.

Overview of The Model of Educational Reconstruction (MER)

The model of educational reconstruction (MER) provides a broadly conceived approach for subject-matter education research (Niebert & Gropengiesser, 2013). The model identifies and interrelates three relevant research tasks of subject matter education: (1) clarification and analysis of science content, (2) Investigation into students` perspectives, and (3) design and evaluation of learning and teaching environments as portrayed in Figure 3.

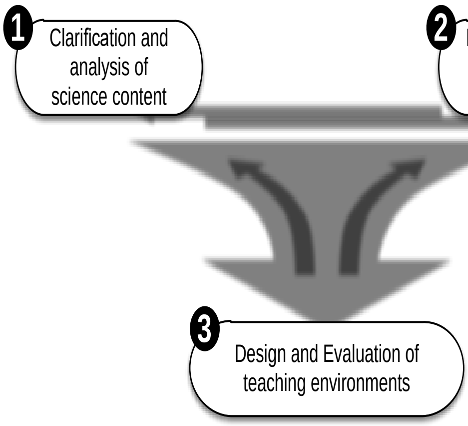

Figure 3: The three components of the Model of Educational Reconstruction derived from Niebert &Gropengiesser, 2013.

From Figure 3, we see that clarification of science content depends on qualitative content analysis of reliable sources such as leading textbooks on the topic under consideration. The idea is to clarify the specific science content structure as constituted by the related conceptions from an educational point of view. Investigation into students` perspectives therefore aims at the pre-instructional conceptions and conceptual development. Observation, design and evaluation of learning environments refer to instructional artifacts, learning situations, and teaching and learning sequences. All these are led by the learning capabilities of the students on one side and the clarification of science content on the other (Duit, Gropengiesser, Kattmann, Komorek, & Parchmann, 2012).

Based on this, the study observed steps to conceptualise the MER as the laboratory DPB. This idea precipitated after a research briefing on the MER by the author. One faculty member (FM) in the Chemistry Education Department of the University of Education, Winneba-Ghana, after the research briefing commented on the MER as:

"The MER resembles the double-pan balance and its operation. It`s better to understand it that way".

(Lilian, 48years)

The above quote made by a FM, led the author to explore evidence on duplicating the MER with a laboratory instrument in a classroom sequence. Evidence of studies on conceptualising the MER with the DPB does not exist from our search in West Africa and Ghana in particular. Hence the goal of our study was to conceptualise the MER as a DPB led approach and let students employ the design as their own direct experience in higher education in Ghana. The following research questions were addressed in the study:

a. What similarities exist between the MER and the DPB?
b. What conceptual experiences do faculty members use to duplicate the MER?

METHODOLOGY

A qualitative, interpretive approach was employed in this research study (Merriam, 1998; Stake, 1995). The study sought to explore faculty members` perceptions and that explored by Niebert and Gropengiesser (2013) on the MER. This kind of qualitative research provided rich description of experiences from faculty members to express the views about their first hand knowledge on the MER. The participants for the study were two (2) faculty members from University of Education, Winneba in the Chemistry Education Department (1 man and 1 woman). The FM conceptions in the two (2) hour discussion were audiotaped twice a week for eight (8) weeks in a plenary seminar on the design of the MER.

Transcripts from the FM and reflective pieces were then read independently in our research team. The statement(s)/quotation were manifestations from FMs` conceptions on the MER. The team met on two occasions to discuss and compare their findings and developed a collective interpretation of the data set by consensus (Stake, 1995; Corbin, 1990). To ensure the quality of the data analysis, all data were externally and consensually validated (Steinke, 2004) through discussion and verified with other studies in science education. The final interpretations of collated data resulted with the discussion in the follow-up findings, supported by verbatim quote that is a representative of the voice from one of the faculty members (FM), using pseudonym.

Out of the generalised observations, the single quotation used in the study is a representative statement from the two faculty members (FM). The extracted MER design in Figure 2 was a probing tool to generate FMs` perspectives on ways to adopt and make duplications of the MER comprehensible to their students. The MER diagram was tabled for discussion, in order to assess the FM`s understanding of how the design could be conceptualised. The study presented other scientists' ideas on the MER so that we could use it as basis to analyse the presentation made by the FM and reflect on the conceptualised DPB.

Operational comparison of the MER and the Double-Pan Balance (DPB)

The main idea of the model is that science subject matter issues as well as students learning needs, capabilities and demands have to be given equal attention (i.e. set in a balance) in an attempt to improve the quality of teaching and learning. There are three main interrelated focal points as referred in Figure 3. This interconnectivity, as stated by Sam, Niebert, Hanson and Twumasi (2015) was a mutual triangulation to foster a balance between scientists` and students` ideas. The categorisation of these points are stated as:
(1) The clarification and analysis of science subject matter including key science concepts and principles such as nomenclature and geometry in metal complexes, isomerism in metal complexes in higher education.
(2) The investigation into students` perspectives regarding the specialised subject including pre-instructional conceptions, affective variables such as interests, self-concepts, attitudes, and skills.
(3) The design and evaluation of learning environments: (a) development of teaching guidelines, (b) development of learning, (c) evaluation of learning environments.

For example, in the educational reconstruction of coordination chemistry, (as was employed in this study), scientists` and students' conceptions were balanced in order to design effective teaching and learning sequence. An elaborated adopted design from Figure 3 is portrayed with Figure 4.

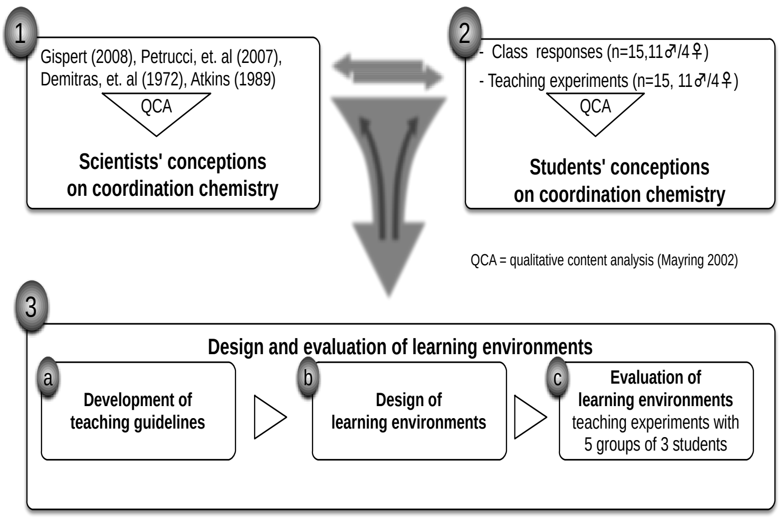

Figure 4: *Research design derived from the model of educational reconstruction* (Niebert & Gropengiesser, 2013)

From Figure 4, the MER is led by students' learning capabilities on the left hand side (2) and science content on the other hand (1) (Niebert & Gropengiesser, 2013). In order to let our students appreciate the MER design, and engage with it appropriately, the study linked the design of the model (that is, the MER) to a laboratory DPB to serve as a concrete picture of how the model works. The result of this comparison is represented in Figure 5.

Figure 5: A laboratory DPB as a representative idea of the MER.

In the representative model from Figure 5, students' ideas were conceptualised as items in one beaker and the scientists' ideas as items in another beaker, which were adjusted by adding on or taking away until a 'true' or `authentic balance` was achieved between the two perceptions- in this demonstration, items in the beakers.
An expression of the components and operations between the MER and the DPB is represented in Table 1.

Table 1: Comparison of the MER and the Double-Pan Balance (DPB)

Item(s)	DPB	MER
Basic components	Three	Three
Entities (1)	Weighing pan 1	Clarification of scientists` conceptions.
(2)	Weighing pan 2	Investigations into students` conceptions.
Refinement (3)	Balance bar	Design and evaluation of learning environments.
Balancing	Horizontal pivoted lever arms	Up-down referral arrows.
Process Orientation	Iterative	Iterative

From Table 1, both the MER and the DPB have three (3) basic components: (1) two weighing pans 1 and 2 are similar to the scientists` conceptions on the left hand side and students` conceptions on the right hand side, as described in Figure 4. The balance bar served (Corbin, 1990) as a correctional factor to fine-tune imbalances in the DPB whilst the design and evaluation of learning environments did similar operation for the MER. In all, both designs focused on iterative processes with center marks setting out balances either with the horizontal pivot level in the DPB or up-down referral arrow positions in the MER. A representative DPB is interpreted as the MER and portrayed in Figure 6.

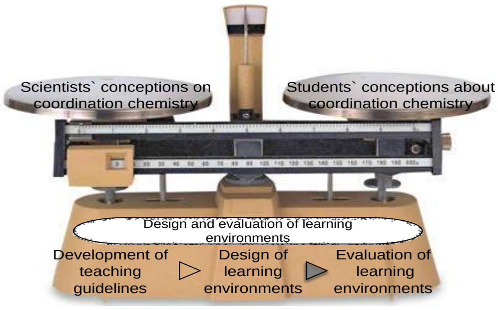

Figure 6: A conceptualised MER (A representative of the DPB) designed by one of the faculty members

The Figure 6 above serves as direct concrete picture of the MER. Students in this situation would view and appreciate the new design (DPB) as a direct experience in the discussion of how the MER works.

Conceptual experiences exhibited by the Faculty Members (FM)

Recent research shows that, in contemporary research there is certain one-sidedness in a number of conceptual change approaches to overemphasize the students' perspective and neglect the science perspective to some extent. There is also the tendency in aligning to more traditionally oriented approaches. That is, to put the key emphasis on the science point of view as guideline of planning instruction for students. The result of this perpetual shift, either to the left or right side of the balance as expressed above could be portrayed in the DPB conceptualised MER design in Figure 7.

Figure 7: The DPB portraying one-sidedness of most contemporary research

From Figure 7 above, there are group of science educators who are glued to particular science (on the left hand side) domain. Their intentions and attention is not only near to teaching practice but they also put the main emphasis on science content in designing new teaching and learning sequences. Frequently, a balance between science orientation and orientation on student needs, interests, ideas and learning processes (on the right hand side) is completely missing. On the other side, the group focussing on empirical research on teaching and learning often orients themselves to general education and the psychology of learning barely considering the domain and context specific perspectives of the science topic. A significant number of conceptual change approaches (Vosniadou, 2008; Treagust & Duit, 2008) seem to fall into this category. These two (2) positions are defined by the terms science-oriented and student-oriented approaches to research. Recent research has clearly shown that tribute has to be paid to science-oriented and student-oriented perspectives with equal importance. The approach adapted by Sam, Niebert, Hanson and Twumasi (2015) sought to bring science content structure issues and educational issues into a balance and–putting them on equal-leveled weighing pans. That study helped to avoid the one-sidednesses mentioned earlier by not putting main emphasis neither on the science side nor on the students' side as it is represented in the conceptualised design in Figure 6. Again, the DPBA introduces the nurturing of students intuitive conceptions to be in balance with the scientific conceptions. In this manner, a science expert, who doubles as the facilitator and the evaluator of the scientific ideas, brings the scientific perspectives on-board. In this process learners' experiences become educative through reflections on the scientific tools provided by the science expert (That is, dwelling on careful, active and persistent consideration of any alternative or supposed form of knowledge not in compliance with scientific ideas). This discourages the fact that scientific knowledge is static of accumulation of facts (Gregoire, 2003) causing imbalances in cognitive thinking.

CONCLUSION

With the growing trend in educational research approaches such as the MER-having the intention of elementarising science content structure to make it comprehensible to students. The study therefore puts forward another direction in understanding educational research designs (such as the MER) through conceptualising some of these designs with available standardised laboratory apparatus, thereby exposing science educators and students to a direct but second-hand live experiences such as the DPB approach.

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