From Knowledge to Wisdom

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1840 Industrial Drive, Suite 160, Libertyville, Illinois 60048
Tel: 1-847-281-9862
Fax: 1-847-281-9855
E-mail: teacher@davidpublishing.com, edu1658@yahoo.com

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Realities of Curriculum and Teaching: Revelations From Singapore Teachers’ Meta-reflections

Tang Wee Teo, Aik-Ling Tan
Nanyang Technological University, Singapore

This study examines four Singapore teachers’ reflections on issues and problems in their teaching practices. As an insider-outsider or educator-researcher seeking to understand the complexities of teaching, we interrogated the teachers’ beliefs, dilemmas, biasness and prejudices embedded in their reflective narratives on experiences in curriculum work within an education system which is dominantly centralized and highly routinized. The teachers reexamined taken-for-granted practice and beliefs, and revised their written reflections. The recursive process of reflection and meta-reflection reveals more critical insights into the curriculum work and teaching. This shows that superficial forms of reflections are easily constructed, but critical reflections, especially on race and gender issues in teaching, tend to be ignored. Analysis of the reflective narratives written by the teachers showed divergence in their experiences as science teachers despite of teaching in a seemingly centralized and homogenous system. The findings suggested that interrogation of teachers’ reflections could provoke more critical and in-depth reflections on normative teaching practice and offer teachers a platform for their voices to be heard.

Keywords: science curriculum, reflection, meta-reflection, teaching and learning, Singapore teachers

Introduction

Reflections entailed retrospective re-search, continual re-examination, and critique of normative practices in teaching in order to invoke new ideas for change. Such a process encapsulates the intricacies, details and complexities of past events, activities and ideas in dialectic with the present and transcendence into the future. Frameworks and guidelines could systematically guide practitioners in making reflections or limit it and reflection is caught in a web of interconnectivities rendering reflections and the process of reflecting unsystematic, confusing and even disturbing. Superficial and deep feelings of pride, hubris, guilt and regret are generative, making reflections uncomfortable and at times cathartic.

Reflection is an active process of being aware of one’s experiences so that we can give attention to the experience and explore new insights. Reflection helps professionals to understand why they do and what they do. It gives meaning to an action which has taken place. By being sensitive and curious about our experiences, we are provided with powerful learning experience which we cannot be derived from books or formal training. Gaining insights into our experiences helps us to be more focused on and purposeful in our practices. Reflection can also help to translate learning from our experiences into reality. Researchers have, however, cautioned against treating reflection merely as an intellectual exercise (Boud & Walker, 1998), but rather to
engage in “active, persistent and careful consideration” (Dewey, 1910, p. 6).

To make possible the dialectical relationship between reflection and change of practice, Schon’s (1983) suggested the notion of reflection-in-action and reflection-on-action. Reflection-in-action is often described as “thinking on our feet”. It is an act which involves looking at our own experiences, connecting these experiences with our emotions and harnessing on the theories which we use at that point. It is also about building new understandings to inform our actions in the situation we are in. Reflection-on-action usually takes place after the event and adopts a “look back” mode. Both forms of reflection are important as they complement each other in helping to enrich the understanding of experiences.

Reflection can be done as an individual or as a group depending on the goals which are set. In schools, self-reflection illuminates personal practices of an individual’s classroom teaching while peer-reflection informs collective and group practices. Again, self- and peer- reflections complement each other mutually. In this paper, we relied on self-reflection to illumine teacher’s personal ideas about issues and dilemmas they faced in their practice.

**Purpose of This Study**

We have three goals in this paper. First, we want to illuminate problems and issues Singapore teachers face in curriculum work and strategies they have devised to manage them. Their situated school contexts as embedded within the larger context of a national curriculum illuminate that how negotiations in the multiple systems of constraints are made.

Second, we want to challenge and delimit the boundaries of reflections as an internalized, personalized and static experience into externalized, critical and fluid forms. Writing reflective narratives necessarily entails the reconstruction of past experiences, beliefs, inner feelings and assumptions into stories that could be shared. We incorporate our own views and personal stories as we relate to the teachers’ narratives to show that we have personal interests in their lives. This encourages rapport-building between the researchers and teachers.

Last, we want to test out our idea that teachers would reflect more critically if their reflections are subjected to repeated interrogations. Being able to reflect critically is not an innate quality. People are usually caught in their own biasness, prejudice, or enframed thinking to see other possibilities or angles. As such, being critical about one’s own practice entails struggling in making interpretations and definitions (Bennet, 1980). The experience is typically non-solitary and does not guarantee insights (Giroux, 2001). In this research, we want to demonstrate how conventional reflections could be transformed into critical reflections. As insiders-outsiders or educators-researchers, we facilitate their process to becoming critical reflective practitioners. This study, thus, has catalytic validity (Lather, 1986b), as the research process could provoke teachers to think and “act otherwise” (Freire, 1985).

**Methodology**

In this study, we act as insiders of educational research and outsiders of the teachers’ classroom to facilitate the teachers’ reflection process. We purposefully engage our subjects—four Singapore teachers—as research collaborators in the reflection and meta-reflection process. The research design entails “progressive focusing” (Parlett & Hamilton, 1976; Stake, 1995) and “reciprocity” (Lather, 1986a).

Using these teachers’ initial reflections on broad questions related to their professional and educative experiences and thoughts, we teased apart their reflective narratives to ask new questions and make comments.
The two questions asked were:

(1) Describe your experience in science curriculum making and teaching;
(2) What are some factors you consider in reflecting on the curriculum and teaching? How are these factors important or significant?

We read the teachers’ narratives and asked new questions to incite new or revised thoughts. We looked for points of clarifications, elaborations and examples, hinted at alternative interpretations of the observed phenomena, looked for gaps and asked the teachers if they would consider other factors in their decision-making and read into and tease out nuances teachers’ narratives to have them say more about what is mentioned but seemingly “evade” providing more information. In other words, we deconstructed their narratives to encourage them to reveal more, expose their hidden ideas and critique. For example, when the teachers talked about meeting the needs for students with differing abilities, we asked them if gender, race, ethnicity and class could interplay with the “ability” factor they saw. Hence, we work with these teachers to make them reflect and reveal penetrating thoughts and emotions through “progressive focusing” or “unlayering”. This meta-reflection was an invitation to reexamine what was said, what was not said and what could have been said using a reconstructed lens of an outsiders looking into insiders’ narratives.

We noticed that some critical issues that we wanted teachers to think about or comment on were ignored, neglected, or consciously resisted. We tried to reciprocate with the teachers’ hesitance or resistance by using vignettes of our own experience or quotes from other teachers we have worked with to invite responses. This opened a new window to extend the dialogue with teachers. For example, we quoted a US teacher saying, “Chemistry is Chemistry” which means there was no way he could make the chemistry curriculum address gender, race, ethnicity, or class differences. Chemistry, to him, was self-contained, asocial, acultural and apolitical. We borrowed the words of this teacher from a different socio-cultural and socio-political context to invite the Singapore teachers to comment or critique what he said and offer their views.

The Four Singapore Teachers

The four teachers (pseudonyms given) were approached by us as we had previously worked with them in schools. The profiles of the teachers are tabulated as follows (see Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Jessie</th>
<th>Kathy</th>
<th>Sonia</th>
<th>Gordon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Level taught</td>
<td>Elementary</td>
<td>Secondary</td>
<td>Elementary</td>
<td>Secondary</td>
</tr>
<tr>
<td>Educational level</td>
<td>Bachelor of Business (with honors)</td>
<td>Bachelor of Science</td>
<td>Bachelor of Science</td>
<td>Bachelor of Science</td>
</tr>
<tr>
<td>Years of teaching experience</td>
<td>5 years</td>
<td>8 years</td>
<td>15 years</td>
<td>4 years</td>
</tr>
</tbody>
</table>

In following, we present the four excerpts of the teachers’ reflective and meta-reflective narratives.

Jessie: “Finally Someone Is Listening”

Teacher’s Background

I am an elementary school teacher. I teach a class with 29 grade one pupils English, mathematics and social studies. At the same time, I also teach a class with 24 grade four pupils science. The small enrollment in
each class is unusual (and likely to be temporary), since the school is relatively new. Being a teacher, in charge of the grade one class, means that I have a lot of administrative duties. Each week, I conduct a Form Teacher Guidance Lesson to get to know my pupils better through planned activities. Besides that, I also conduct lessons on life-skills like folding clothes. Besides classroom teaching, I serve in three committees in school—Science, NESS (National Education and Social Studies) and Pupil Leadership. It is a norm in schools for teachers is to be in at least two project committees. I also serve in other ad-hoc projects committees, such as the school appraisal committee and well, the list goes on.

Problems in Curriculum Work

With the change in the primary science syllabus in 2008, the task of interpreting the syllabus seems to get tougher due to the limited information found under the “learning outcomes” section. Many of my colleagues do not even bother to refer to the new syllabus when they teach. Most of them teach according to the teaching materials available especially the textbook adopted by the school. This is something which I can not understand and the publishers are also trying to interpret the science syllabus. Some teachers will teach according to what they remember based on the old syllabus. I am guilty of that too. Hence, it is imperative for teachers to come together and explicitly define the learning outcomes they want to see in their students. However, due to various reasons, priority is not given to truly and fully understand the Primary Science curriculum in my school.

I am also given limited access to and opportunity in writing, planning, designing and revising the school’s science curriculum. There is not a specific school’s science curriculum anyway. Most of the time, teachers just follow the SOW (scheme-of-work), provided by the publisher with some refinements here and there. The activities spelt out in the SOW written by publisher could include activities or learning outcomes that students are not required to learn. For instance, many textbook publishers tried to include as many kinds of plants and animals in the textbook but students are not required to know the specific name of organisms in the examination.

Reflecting and Reflections

Reflecting on my teaching and lesson delivery is something that I hold dearly to. After each lesson, I would reflect on how the lesson was delivered, the learning environment perceived by the students and the engagement of the students and most importantly their understanding of the concepts taught. More often than not, I would also come out with activities or questions for the next lesson to gather feedback from students. It is important for students to fully understand each concept before moving to the next. I prefer to set diagnostic tests to assess their understanding. It is something concrete and students can refer to them when they revise for examinations as compared to mere questions asked in the classroom. I reflect in five areas of teaching and learning: experience of learning, tone of environment, assessment, learning content and pedagogy.

In my school, it is mandatory for the teachers to reflect upon their teaching. We have to reflect using the guiding pointers and state three things that went well in the classroom, two things that did not work so well and lastly, one thing one would like to do in order to improve the lesson in the future. The only eyes for teachers’ reflection are the reporting officers and no one else. But, teachers would be able to share their experiences and reflections during the teachers’ timetabled time. During this one hour, teachers with the same teaching level come together, sharing ideas to improve teaching and learning. However, this is not done for science. This could be due to the small number of science teachers available in each level and furthermore, teachers in primary school do not only teach one subject. I have to teach English, mathematics and science across two levels. Greater effort is needed to allocate time for science teachers to share with one another. This not only
provides a pillar of support for the science teachers but also addresses any misconceptions if there are any ones. My greatest fear in teaching primary school science is teaching students the wrong concepts without myself knowing. It is very difficult for students to unlearn the wrong concepts hence they have to learn it right at the very first time. To be honest, I feel inadequate as a science teacher without a science degree.

**Strategies to Overcome Problems**

In order to overcome the inadequacy in science content, after I became a trained teacher, I attended courses to improve my science content. I took a few modules under the Advance Diploma in Science just to make sure that I am teaching the right thing in the classroom. Only then, I realized that constant upgrading is important for teachers to sharpen our tools in order to stay relevant and effective. Teachers cannot stay stagnant with the skills that we learnt years ago. Since time is a scarce resource, no one can possibly learn everything. Hence, sharing among the teachers is important. Sharing, in my opinion, is a form of professional development for teachers. Sharing of “best practices” helps us to zoom in to the instructional strategy that works with students and this is especially helpful when teachers are always short of time to complete the curriculum. Personally, I have attended many sharing sessions and workshops conducted by teachers in the cluster schools. Some are helpful and others are not so. I believe sharing should start at school level and should be done as often as possible. It should not be confined to timetabled time, but as and when the need arises.

**Kathy: “Two Mirrors Facing Each Other”**

**Teacher’s Background**

I am a biology teacher in a high school for girls. Besides teaching biology, I also teach values education and am a form teacher to a tail-end (lowest ability group) grade nine class. I am a member of the school’s discipline committee, but my main job is to prepare the students for morning assembly everyday. I serve in the examinations committee where I can be doing things like the examination timetable, invigilation schedule, seating plans and setting up central location for examination. To add to the list of duties, I am also the subject coordinator for biology where I conduct professional sharing sessions (white space), ensuring every student fulfils their SPA (science practice assessment) portfolio requirements, coordinating the SPA assessments, marking the exam scripts for alternate years and vetting questions of formal assessments.

**Reflecting and Reflections**

Reflection for me is on-going. I do not particularly reflect on specific things but generally everything around me. I remember going for two renewal courses and it was utterly painful and contrived. Because the reflection process was structured and guided, we had to do group work and produce evidence of reflection. I am personally not a writer or an artist, so using such media was unnecessary and tedious. I would rather go for a walk in a park and talk about controversial issues with a friend. I find more meaning in the latter. During the renewals, we were put in groups and obviously how can one reflect so deeply with group members whom you have not built any trust yet. So, I think schools should not have structured reflection sessions, because it gives this very personal and meaningful activity a very bad reputation. The people who have to conduct it can sound very strained too because they know what it is like to be in the audience. This can happen as some of us have a very packed timetable and are in no frame of mind to slow down and reflect, because there are so many other things to attend to. So, people cooperate to shorten the process. This is the sadness of not being able to reflect. I think a lot of this boils down to personality. Despite of all the structures, some people are still doing the stupid
things repeatedly. But that is the extreme.

Personally, I do not reflect by having an allocated time or by method of journaling, etc. A lot of it comes during the lesson itself or when I am reminded of something and when I read or watch television program. During the lesson itself, I find that when I teach a difficult concept I share my thoughts by “thinking aloud” with the pupils. When that happens, I get to see how they are reacting to the way I present that idea. At the same time, I encourage them to ask questions and clarify, so through this process we learn together. As thinking aloud, I make it a point to present the idea generally in two ways—a broad idea version to keep the minds of those who have the aptitude to understand an open, simple and less complex version for those who need more time and take comfort and security in “just learning this”. When I realize that the kids are really into something, I take the opportunity to introduce or link them to other concepts, ideas, or stuff I have seen, read or experienced. This leads the class discussion to other related matters as well. I usually let them indulge until they start to digress to something too far off. Though I may not be able to finish what I want to teach, I take to heart that they have learnt something that they want. The time spent is at the expense of the syllabus, but we can always catch up later. I may have used the same time to dwell on the harmful effects of smoking, but if they are not with me, all the time would have been wasted. However, I see value in telling them about my uncle and my father and their experiences with the habit. Somehow pupils are very interested in their teacher’s lives, so I would tell them about my grandfather (an opium trader before the war), my father who picked up opium smoking, subsequently to cigarette smoking when opium became illegal and my uncle who had smoker’s cough until he burst blood vessels in his lungs and started vomiting blood.

I suppose, whether one reflects or not depends very much on their personality. There are some people who are so blind to themselves that they do not realize the impact they create in the way they behave. Or maybe, they just refuse to admit it. I think it is impossible to get people like that to reflect. Then, there is the other extreme where they become so pre-occupied with what others think of them that they become over-sensitive and worrying too much about what they just did or said. I think in order to reflect effectively, one must have the humility and courage to admit their wrong-doings and have the motivation to change to themselves better. Reflection can be quite disconcerting for most people because it opens the skeletons in their closet. Some people are afraid to open the closet for fear of being judged and others open their closets but put on a facade and return them into the closet. There are those that open the closet, letting them go and move on. I think it is hard to encourage others to reflect unless it is demonstrated through casual conversation and sharing which begets more reflection from the conversing partner and it usually spirals into a meaningful conversation from there. Any reflection that is too explicit becomes futile exercise because people feel obliged to say what is expected of them. So, responses can become contrived and text-book answers like just to get on with it.

I never really found sharing of best practices very effective. Only a few get my attention, maybe because some of these practices are not new. Most of the time, it does not fit into the context of my school and it is not my character to do certain things. I think it is good to share but no one has really monitored how effective these sharing sessions are and how the presenters and participants really feel about the whole affair. Or it was the whole point of the exercise to fulfill other agendas.

**Sonia: “From Personal and Private Reflection to Dialogic Reflection”**

**Teacher’s Background**

I taught elementary school science for 15 years and I am currently the head of science department in school.
The students I teach come from privilege family backgrounds and the students are generally high-performing. Besides teaching, I am in charge of the administrative and curriculum matters in the science department. As a head of department, one of my primary tasks is to mentor beginning teachers who join the school.

**Reflecting and Reflections**

As a classroom teacher with 15 years of teaching experience, reflections can sometimes take place instantaneously during lessons as we are teaching. Looking back at my practice when I first started out as a teacher, I do not see it possible that I could have been able to do that as a beginning teacher. Due to inexperience, response would be more delayed when it came to reflecting on the day’s lesson. Ability to reflect instantly is developed through experience as we become more confident and at ease with the flow of lesson. We are also more adaptable and less fearful of impromptu changes during lessons (from what was previously planned). It could be triggered by unexpected responses of pupils that prompt us to rethink what we could have done at the earlier part of the lesson that could have resulted in it. This helps us revise our next plan of action immediately. However, I usually reflect upon my practices when I am reviewing pupils’ responses in their written work. Like all teachers, my reflections are driven by the essential question: Why have not my pupils learned? Very naturally, a replay of how the lessons were carried out followed by a series of questions will come to mind: Has the activity been effective in leading pupils to the concept? Or was it the questioning following that was not tight or clear enough? Was the consolidation not comprehensive enough? Besides the day-to-day reflection for improving the next lesson, I reflect upon the general approaches to teaching after the major examinations. The drivers of such reflections are usually the performance scores. The key questions explored are: What are the approaches that I should credit for such performances? What areas have been lacking that I should work on?

As a head of department, I also engage in reflections that centered on pupils’ science learning experience. What kinds of science learning experiences are my pupils taking away after graduating from my school? Looking beyond results, the rigor in scientific skills and thinking and having the appropriate scientific ethics and attitudes are considered. This leads to reflection on the science curriculum, programs and teacher readiness and capacity. There are instances when colleagues are also engaged in such reflections through informal settings over meals or formal settings during department meetings. In preparation for the 2008 syllabus, dialogue sessions were arranged to gather feedback on ways to enhance the quality of science learning in the school. Such dialogues enabled teachers to reflect on their own beliefs with the purpose of science teaching. That session was enriching, as I found that dialoguing stimulated the teachers to question their own beliefs and value systems. Such platforms enable us to verbalize our beliefs. We clarify our own thoughts through discussions during dialogues. Listening to different perspectives relook our own assumptions. There may not be any answers and some teachers find such disequilibrium unsettling, but it enables us to dig deeper towards new-found understanding of our own purpose and roles after listening to different perspectives from peers. While most of the time, reflections is a personal and private activity. When done in the form of dialogue, it can further engage us to reframe our existing knowledge through new perspectives.

**Gordon: “Developing a Deeper Appreciation Through Teaching”**

**Teacher’s Background**

I am a male teacher teaching in an all-girls secondary school. I have been teaching for about four years and
this is the first job that I have since I graduated from college with a Bachelor of Life Science degree. I teach a diverse group of students with very different family backgrounds and also of diverse intellectual abilities. Besides teaching science and biology, I am the teacher in charge of the school band and I assist my colleague in mentoring pre-service interns who are attached to my department.

**Reflecting and Reflections**

When I first entered the pre-service teacher program in 2006, I discovered that I had many misunderstandings and misconceptions about my teaching subject biology. I reflected and thought that perhaps having misunderstandings and misconceptions was a part of my coping mechanism, as a student to comprehend concepts that were rather hard and abstract to understand. I also thought that perhaps my teachers did not really have the time to explain concepts in detail to such a big class and hence the misunderstandings and misconceptions. During the time of my pre-service teacher program, many concepts started to make sense and I developed a deeper appreciation for my teaching subject. I am thankful that I had studied the three sciences in secondary school and junior college and the natural world really started to make more sense from then on as the dots were being connected. Then about a year later, I was exposed to the method of curriculum planning, “Understanding by Design”. It got me thinking about what am I teaching in the classroom. Previously, I was merely going into class and covering the curriculum but this method of planning got me to reflect on what am I teaching. Now, I go into class bearing in mind the “Big Ideas” and it really did help me to teach better and my students could understand better as well. When I reflect upon my lessons, I would consider the level of students I am teaching and their abilities. I will also think about the main ideas that I want them to learn after two years of biology at “O” (a national examination conducted at grade 10) levels. I always ask myself, if there were just a few things that I hope my students will remember in 20 years, what would these things be? Teaching the big ideas are important as eventually, the smaller more minute ideas will fall in place and it will make more sense to the students.

I am lucky to have a very supportive working environment. My immediate working colleagues are very helpful and willing to share resources and experiences. That was very helpful to me as a young teacher and also gave me courage to experiment different teaching strategies. I really enjoyed the intellectually stimulating and professional discussions I have in my department, so did other people from various other teaching institutes. As most members of my department are all seated near each other, it makes professional sharing easy. As and when we have a new idea, we will usually just turn about and share it with whoever is around. This usually happens after a lesson that we considered unusually successful. We reflected on the elements that made the lesson successful and we will proceed to sharing it. As we teach across the different tracked and different types of students, we can now deploy modified methods of teaching in the next available lesson. Having a supportive environment enabled me to try out new concepts and teaching methods.

If anything, I think my three years in teaching has certainly made me a more reflective person in various aspects of my life. I also taught me to be less judgmental and to be more open to ideas. “Agreeing to disagreeing” was perhaps a new insight that never did occur to me.

**Discussion**

**Analysis of Teacher Reflections and Meta-reflections**

Reflections in its internalized form could be solicited and externalized for sharing, critique and extension
analogous to peeling layers of an onion to uncover the core. Kathy advocated using casual conversation and sharing as reflections “begets more reflection”. Reflections through such means were comfortable and generative of more reflections. It encouraged her to reveal dilemmas and identify problems which could normally pass as the norm, tradition and convention. She also developed a unique reflective pedagogy integrating her teaching and reflections with “thinking aloud” techniques.

The teachers’ reflections were associated with their teachers’ roles, years of teaching experience, beliefs about reflections, teaching and learning, personalities and the school structure. In Jessie’s school, it was “mandatory” to reflect and her administrators adopted a structured framework which Jessie felt was helpful in framing her reflections. Kathy argued structured and mandatory reflections and sharing painful, contrived, strained and unnatural experience. She preferred flexibility, space and unlimited time to engage in ongoing reflections—something she felt it was associated with her personality. Gordon, having learned about a curriculum planning framework known as “Understanding by Design”, reflected on the big ideas he wanted students to learn. His reflections were projections into the students’ long-term learning and future. In her position as the Head of the Science Department, Sonia was held accountable to parents and school administrators. As such, her reflections focused on practical issues and goals including students’ results, ethics and attitudes. Her reflections are consisted of the macro-issues on performance scores and micro-issues on the qualitative experiences of students’ learning. She also ensured her teachers engage in dialogue to reflect on such issues. Interestingly, she saw the ability to reflect as related to years of experience. As such, novice teachers were not able to reflect as quickly and react to changes in classrooms.

The teachers engaged one or several metaphors in their reflections and meta-reflections. The implicative complex (Black, 1979) of these metaphors illuminated how they viewed reflections and meta-reflections. For example, Jessie described having structured time for sharing of reflections as the “pillar of support” for teachers. Time was scarce and reflections would be sacrificed, if time were not officially stipulated for reflections and sharing. Reflection was important and central for professional development. Hence, having a designated time for it offered her the feeling of security that it would be done. She valued it but desired it to be heard by others. Kathy said reflections could be “disconcerting” for some people, as though revealing one’s “skeletons in a closet”. The process of reflections requires coming face-to-face with hidden fears which may not be pleasant to deal with afterwards. Gordon described this as “agreeing to disagree” to reflect the internal conflicts as he resolved his dilemmas in the process. Sonia described engaging in deeper reflections as “disequilibrium” to imply the process as shaking, disturbing and uncomfortable for some teachers as they reassessed their teaching and students’ learning. However, it also implied some possibilities of stability after the thoughts become more settled. Kathy viewed meta-reflections as having spiraling effect and two mirrors facing each other and the latter implies reflections as infinite, having no definite beginning and ending points and possibly confrontational.

Despite of several attempts to make the teachers reflect on critical issues, such as the implications of gender, race, ethnic and class issues in relation to curriculum and teaching, none of them considered these factors to be pertinent in their curriculum and teaching. Students’ differences were ability-based, independent of their gender, race, ethnicity, or class. There are three possible reasons for not making distinctions or paying attention to how these factors play out in their curriculum and teaching. First, these teachers are highly educated, representing to top 10% to 20% of the cohort who attended high school and college education and they may not have experienced inhibitions or personal difficulties in learning. Hence, they may not identify
with and understand the real struggles students experience in relation to these issues, family value and conditions and their schooling experience. Second, teachers would never have enough time in curriculum developing and teaching. Reflections become more ad hoc, prioritizing on ways to improve students’ performance scores and grades to in tests and standardized examinations. Deeper and more intricate analysis of additional and controversial issues was possibly avoided to reduce complexities so that curriculum development and teaching could proceed. Third, in the national curriculum, teachers adopted the science syllabi provided by the national agency. The science syllabi stipulated behavioral objectives or science content students needed to learn by the end of grade level. These statements projected the image of science as self-contained and indisputable facts which had been rigorously “proven”, having no relation with the social issues mentioned. Science is hence “delivered” as such. We view this project as ongoing as reflections were temporal, contextualized and subjected to change. We would be continual to track and engage our teachers in meta-reflections, which would subsequently settle as reflections and subjected to reexamination and reconstructed insights.

Teachers’ Experience in Curriculum Development and Teaching

The teachers’ experiences in curriculum development and teaching were related to views, beliefs, confidence level, teacher roles and milieu. Gordon had the least number of years of teaching years among the teachers. He related many of his teaching and beliefs to his pre-service teacher training, saying that the stint helped him to clear misunderstandings and misconceptions he had as a student. Collegiality among his colleagues and milieu were important factors supporting his curriculum development and teaching. In Kathy’s description, she appeared to be independent in curriculum development and teaching, as though she had autonomy in decision-making. She made a conscious effort to relate to students, even if it meant exposing some family secrets and “take to heart” students’ needs. As a result, she had developed strong rapport with students such that she could employ “emotional blackmail” to make some students work harder for her. Jessie revealed her insecurity and the lack of confidence in science teaching without college qualifications in the relevant discipline. She was responsible for following the unrevised syllabus teaching in the same way but was critical of differences in the unrevised and revised syllabus. Her resistance to change made her felt guilty but it also reflected her reclamation of teacher agency in questioning if there were any significant change in the revised prescribed curriculum. Her criticality also showed when we asked her to share her experiences doing curriculum writing in a relatively new school. She questioned the meaning of “curriculum”. She said, “To be very frank, in my opinion, my school does not have a school science curriculum at this point in time unless SOW is the curriculum. We just follow the SOW given”. Jessie questioned if the scheme-of-work—a document summarizing the order of topics, schedule of tests and quizzes and so on—was justifiably called a “curriculum”. Her opportunity in curriculum writing was admittedly limited in the context of the national curriculum which she had to adhere closely for teacher’s accountability. This also reflected the imbalanced power relations in her school context as she implemented the curriculum as provided. Having said that, Jessie and her colleagues taught, according to their interpretations of the learning objectives in the syllabus. In her 15 years of teaching and current role as a teacher and administrator, Sonia’s experiences in curriculum development and teaching differed from Jessie’s, Gordon’s and Kathy’s experiences. She was concerned about students grasping the concepts but acknowledged her focus was on students’ performance scores. She had to be accountable to the school administrators and to ensure her teachers accountable to her and their students. She had to teach and
execute her administrator’s role concurrently. Therefore, in their reflections on their curricular and teaching experiences, these teachers’ revealed dilemmas faced in their work and how they manage these problems or issues by prioritizing what they viewed to be most or more important.

Conclusions and Implications

In this paper, we set out to examine issues and problems teachers faced in their practices and also challenge the boundaries of reflections, taking into account the biases and prejudices teachers bring with them. Working with the teachers and taking the stances of an insider-outsider seeking to understand their world, the teachers’ beliefs, dilemmas, biasness and prejudices were questioned and revealed issues that they have taken either for granted or have given superficial attention to. Tensions in balancing their own preferences and that of the society, parents, pupils and school administration became apparent.

The teachers’ repeated resistance, ignorance, or hesitance to address the critical issues implied that reflections needed to be carefully solicited by some intricate means. Reflections, perhaps superficial forms, were easily constructed. Nonetheless, deeper and uncomfortable reflections attending to sensitive issues needed external stimulus or catalysis to purge. The process also had to be developmental rather than instantaneous. Further, reflections embodied situated meanings and personalized thoughts and feelings. Hence, questions and prompts grounded in the teachers’ narratives of reflections were more appropriate than generic ones.

The four teachers reflected on their experiences about curriculum and their practices within an education system that is dominantly centralized and highly routinized. Schools have a set of fixed science syllabus that is geared towards the national examinations and teachers generally have to “teach to the test”. As such, their experiences with authentic curriculum planning and design are at the best one of interpretation and implementation of a curriculum that is “prescribed”. In spite of this seemingly constrained context, these four teachers differed in their experiences as science teachers, both in terms of their ideas about the curriculum and their ideas about reflecting on their professional practices. All the four teachers spoke about their own practices and experiences in relation with some forms of others—Kathy related her preference of non-structured reflection to a structured one school administrators generally prefer and adopt; Jessie identified her guilt of using the old syllabus to the practices of her colleagues; Sonia related her concerns about her role as the head of department in relation to school and parental expectations; and Gordon spoke about his teaching experiences in relation to a new curriculum framework. While it was evident that the teachers avoided controversial issues of gender, race and differing students’ abilities in their narratives, they related their own preferences, beliefs and experiences to the norms of the contexts they lived in. This, we argue, showed that the teachers could be reflexive in their practices (Chiseri-Strater, 1996), albeit relating to a different “other”.

References


Pair Programming and LSs in Computing Education: Its Impact on Students’ Performances

Tie Hui Hui  
SEGi College Penang, Penang, Malaysia

Irfan Naufal Umar  
Universiti Sains Malaysia, Penang, Malaysia

Learning to programme requires complex cognitive skills that computing students find it arduous in comprehension. PP (pair programming) is an intensive style of programme cooperation where two people working together in resolving programming scenarios. It begins to draw the interests of educators as a teaching approach to facilitate learning and improve programming performance. The approach of PP, its model, benefits and limitations as well as the LS (learning style) preference are presented in the first part of this paper. The research findings and discussion on the application of PP involving 96 first year computing students are incorporated in the second part of this paper. The participants in these two intact classes were randomly assigned either to the experimental group that received PP or to the control group that received DI (direct instruction) method only. In PP group, students worked in pairs based on the visual-verbal LS dimension and those of DI group work individually. During a seven-week treatment, both groups applied program flowcharts and pseudocode in solving programming tasks. This study used two assessment methods—the formative and summative to examine the students’ programming achievements. Two programming assignments were used as a formative assessment tool, also the CPPT (computer programming performance test) as the second tool which comprises of a pre-test, an immediate post-test and a delayed post-test, was administrated to assess the students’ programming recall and retention. The result findings indicated that students in PP group significantly outperformed those in DI group for both the formative and summative assessments. However, only the visual and verbal students performed significantly better in recall than the retention. The analysis on the interaction effects revealed that learning is within inner self with regard to the instructional strategies applied and LS preference in classroom environment. In this case, the effectiveness of instructional strategies adopted to foster learning somehow depends on the type of learners. Therefore, educators should reflect on individual learning abilities while applying PP to stimulate students’ engagement and critical thinking skills that subsequently will have positive influence on academic performance.

Keywords: PP (pair programming), cooperative learning, LS (learning style), computer programming

Introduction

Computer programming being the essential element of the computing courses curriculum in science education is the main building block for most students who are pursuing programming courses. It takes courage and audacity for the first year computing students as novices to learn how to programme. As programming demands complex cognitive skills, planning, logical reasoning and problem-solving eventually play their roles.
in the process of learning. Understanding the basic programming concept is one of the three primary pedagogical goals of learning and teaching programming, besides creative, logical and critical thinking skills (Miliszewska & Tan, 2007; Fincher, 2006). McGill and Volet (1997) noted that computing students encounter intricacies in acquiring conceptual understanding over the novel concepts while learning the most fundamental syntaxes. In fact, problem-solving and critical thinking skills which these novices lack are the ultimate skills sought after in following programming courses. To increase productivities, programming skills and higher quality of codes and minimize errors and deduce coding anxiety, programmers in software development industry frequently cooperate in their daily tasks on the design, coding and testing.

PP (pair programming) is a structured mode of cooperative learning approach that could be an added benefit when it is introduced and used in a form of method as the instructional strategy in educational environment (Kuittinen & Sajaniemi, 2004). Meseka, Nafziger, and Meseka (2010) as well as Hamer (2006), revealed that cooperative activities in classrooms typically promote richer social interaction, enrich critical thinking and enhance attitude of students in the process of programme development. Pairing activity assists both members to interact, discuss and brainstorm on the given problem scenarios in order to accomplish common programming goals. With an effective interaction between pair partners, it improves conceptual understanding on the abstract concepts in each learning opportunity. This further develops higher cognitive knowledge that leads to improve the students’ programming proficiency and subsequently reveals positive impact on their academic performance. Through in-depth discussions and details explanation with their peers, Ballantine and Larres (2007) found that the high achievers benefited the most from their participation in the heterogeneous pairs, specifically with the diversity of thought that fosters the learning process. Besides, social interaction is another skill that computing students are lacking. Thus, these skills are crucial for students who are to be successful in future software development profession.

In general, LS (learning style) is described as an individual preference in approaching and acquiring new knowledge. It is a relatively stable indicator of how learners receive, organize, interact with and present information in the context of learning (Ladd & Ruby, 1999; Kolb, 1984). Empirical findings revealed that differences in LSs are correlated with students’ academic progress and subsequently affect their programming performances (Pallapu, 2007). Educators are persistently looking for alternatives in ensuring that students attain better results in programming comprehension and logical thinking which are vitally needed in the software industry. PP as cooperative learning in due course could nurture these key skills that eventually inspire students to thrill while learning programming.

PP in Education

PP, as cooperative learning, is a style in which two people work together at one computer station (Beck, 2005). They consistently cooperate on the design, algorithm, code and test. One person acts as the “driver”, writing the design of codes manually. While, the other person acts as the “navigator” who observes, guides his partner and actively engages in selecting the best methods for coding the programme as well as simultaneously scans for errors in the programming codes. Intermittently, these roles are interchanged between the “driver” and “navigator” for the benefits of both partners. Through pair activities, the “driver” and the “navigator” communicate and brainstorm at any one time on the problem scenarios towards the development of independent learning in problems-solving.

In this study, students were to work in pairs and solve programming problems by applying program
flowchart and pseudocode without using computers. Figure 1 shows that the students work face to face, discuss and interact in pairs to solve programming problems or complete computer programming assignments in class sessions (without practical sessions). During the pair discussion (social interaction), a shared set of common associations or attributes developed by both partners is used as a communication tool which allows the transferring of knowledge between both members (see Figure 2). Once the common terms used for the narrative of the problems scenarios are established and created in the mental model of both the driver and navigator, the interaction of conceptual schemata between them become possible. Working cooperatively in pairs that interactively engage to verbalize problems scenarios builds complex mental schemas which trigger higher logical thinking and reasoning skills (Gibbons, 2008; Gillies, 2007; Ballantine & Larres, 2007). This in turn improves the students’ confidence levels and attitudes towards programming.

![Figure 1. Pair discussions to solve programming tasks.](image1)

Roles of driver and navigator. PP applies the concepts of “driver” and “navigator” for two students to work cooperatively in solving and completing programming tasks. The terms “driver” and “navigator” elaborate the role of each partner in the pair. The student who is the “driver” has current control on writing the program codes, while the “navigator” contributes to the tasks verbally by checking through the program logic of the written codes (Bryant, du Boulay, & Romero, 2006). The student, who acts as the “driver”, writes the design and develops the program codes based on the problem scenarios. He/She converts the novel problems into program solutions through the use of program flowcharts and pseudocode. At the same time, the other student who acts as the “navigator”, observes, guides the “driver” and provides constructive feedback on the programming codes (Adams, Lubega, Walmsley, & Williams, 2004). This could be further concluded that the
“driver” works on the syntactic/conceptual knowledge, while the “navigator” contributes to the strategic/conditional knowledge as indicated in the McGill and Volet’s (1997) conceptual framework.

The “driver” and “navigator” communicate and brainstorm at any one time in order to stimulate higher cognitive thinking and make their comprehension strategy explicit which enhance the learning process. The role rotation is done periodically between the driver and the navigator so to further promote effective learning where the knowledge is constantly exchange between the members in pairs (Xu & Rajlich, 2005; Srikanth, Williams, Wiebe, Miller, & Balik, 2004).

**The benefits from pairing activities.** A wide range of potential benefits to PP have been identified and reported in the literature. In an academic environment, working in pairs helps the students have deeper understanding of the design and solve complex programming tasks in shorter timeframe with less errors (Bryant, Romero, & du Boulay, 2007; Tomayko, 2002). Research results indicated that students working in pairs develop higher quality codes resulted in better programming performance, increasing satisfaction, reducing frustration, increasing confidence on program outcomes and superior results on graded assignments than those who work individually (VanDeGrift, 2004; Williams & Kessler, 2003). Discussion between partners in pairs enforces peer learning which offers richer social interaction, thus, helps each member to solve novel problems and complete the given tasks together. These results have proven that PP positively impact students’ learning. Alternatively, this pairing activity is another promising instructional method to be considered for effective learning programming skills.

**The limitation of PP.** Despite of the fact that PP shows positive effects on learning processes and programming skills, there are still some foreseen obstacles in this instructional method. The first is the technique used to pair students. Pairing the students based on their past experience and knowledge is one of the options, which could maximize the individual programming abilities in solving novel situations. This further allows the students to learn from each other in a team of two. Another option is to let the students decide whom to pair with and which is to minimize the incompatibility between members in the pair. The second concern is the scheduling. The two partners need to have the common working schedule. They may not be able to work in pairs on the given tasks when their schedules overlap. The third drawback is the level of difficulties of programming scenarios. Theoretically, PP approach is ideal for solving novel problems that generate a medium programme size of codes (Xu & Rajlich, 2005). However, some novel problems may positively encourage and motivate students to comprehend better than that of others. Costing (the fourth issue) is the increase in labor cost. In practice, people are paid to do the job of one, while working in pairs requires extra manpower and in turn generates additional labor cost (Begel & Nagappan, 2010). Lastly is the difficulty in assessing the students’ individual effort and programming abilities. It is not easy to measure the contribution of each partner in PP situations, which the partners may receive undeserving credits for the successful completion of programmes (Hahn, Mentz, & Meyer, 2009; McDowell, Hanks, & Werner, 2003). As such, two different assessment methods could be taken into consideration: One is to assess the individual performance while working in pairs, and the other is for pair assessments (Verhaart, Hagen, & Giles, 2005; Parsons, 2004).

**Learning Style (LS)**

LS is a preferred learning mode in which students respond to and use stimuli in the context of learning. For James and Gardner (1995) and Kolb (1984), it is the way in which students perceive, process, store and recall facts. In educational psychology, styles have been classified and acknowledged as the prime construct.
that serve as relatively stable indicators of how students respond to the learning environment (Deborah, 2005; Felder, 1993). This particular style reflects students’ cognitive styles and shapes their own approach in acquiring and processing information and strongly influences their programming progresses when they approach a learning task.

**Visual LS**

Visual learners get more information and remember best from what they see, such as pictures, diagrams, flowcharts and demonstrations. Most students undertaking science courses are visual learners (Richardson, 1984; Barbe & Milone, 1981), while most lectures in basic computing curriculum are verbal—The information presented is predominantly auditory or visual presentation of auditory information (Tie & Irfan Naufal Umar, 2010). It has no surprise that students fail to reproduce information which was presented to them not long before as it may have been probably forgotten.

**Verbal LS**

Verbal learners remember and understand best from what they hear and then say. They enjoy activities which emphasize on discussion and get a lot out of it. Furthermore, these students learn effectively by explaining things to others. Information presented in most courses is verbal—spoken words in lectures, written words, formulae in texts and on the whiteboard. As such, both visual and verbal modalities representation are to be added to accommodate all students irrespective of their LSs preference in order to reinforce effective learning.

**Research Questions**

In this study, six primary research questions have been identified and formulated to address the research outcomes that:

1. Are there any significant differences in the quality of codes written between students who received PP treatment and those who received DI (direct instruction) only?
2. Are there any significant differences in duration for completing the programming assignments between students who received PP treatment and those who received DI only?
3. Are there any significant differences in the number of errors made between students who received PP (PP) treatment and those who received DI only?
4. Are there any significant differences in recall and retention between students who taught in PP and DI instructional methods?
5. Are there any significant differences in recall and retention between visual and verbal students in learning programming?
6. Are there any interaction effects between instructional methods and students’ LSs preference for recall and retention performance?

**Research Methodology**

The purpose of this study was to investigate the effects of PP strategy in learning the basic programming concepts on the students’ programming performances in terms of assignment comprehension, recall and retention amongst computing students. This study was further extended to include LS factor that served as the moderating variable for examining the differences in recall and retention between both visual and verbal students in learning programming. The interaction effects between instructional method and LS preference of students in programming performance were also analyzed. The emphasis of this research was on whether
cooperative learning through PP in classroom environment is an effective alternative solution in programming education as compared to the DI approach that involves individual learning.

Research Design

A $2 \times 2$ quasi-experimental design was used to examine the effects of PP on the five dependent variables with LS (visual and verbal) being the moderating variables. The three dependent variables—quality of codes, time taken and errors made were used to assess the students’ performances in programming assignment. The recall and retention being the last two dependent variables were based on the immediate and delayed post-test scores. A total of 96 first year undergraduate computing students participated in this study. They were randomly assigned to the two treatment groups. The experimental group consisting 48 students received the PP treatment and the control group ($n = 48$) received the DI treatment.

Research Instruments

In assessing the continuous learning progress of acquiring the programming concepts and skills, two programming assignment questions were used to measure the students’ achievements during the learning activities. This formative assessment is to determine their learning efficiency throughout the course duration.

The Felder-Soloman’s ILSQ (index of learning style questionnaire). This instrument based on the Felder and Silverman’s (1988) LSs model was used to access the students’ LS preference prior to the treatment. The existing ILSQ instrument consists of four learning dimensions. In this study, only one dimension measuring the visual and verbal LS is applied (Cronbach’s Coefficient alpha of 0.78) (Zywno, 2003). This instrument uses a multiple choice format in presenting options. The students who responded mostly “a” in the questionnaire were classified as visual learners and those who respond mostly “b” were identified as verbal learners.

The CPPT (computer programming performance test). A pre-test was used to assess any initial differences in terms of programming performance between the two treatment groups prior to the treatment. The immediate and delayed post-tests of CPPT as summative assessments were administered to measure the students’ recall and retention. The immediate post-test was administered immediately after the treatment and delayed post-test was conducted one month after the treatment. Both tests were designed based on the McGill and Volet’s (1997) conceptual framework to assess the theory and practical knowledge of the basic programming concepts, especially in the topic of sequence and selection.

Data Collection Procedures

The experiment was conducted for a seven-week duration to the two intact classes. These classes from the first year computing programme were randomly selected and assigned to one of the two treatment groups: the PP group or the DI instructional strategy group in learning the basic programming concepts. The ILSQ questionnaire was administrated to these two groups prior to the treatment in order to classify the students as visual or verbal learners. The pre-test was first administered to these two groups of students before the treatment in order to collect the baseline data on their programming knowledge. During the treatment, the students in both groups received program flowchart and pseudocode in learning the basic programming concepts: (1) sequence; and (2) selection constructs.

In the PP group, the roles of “driver” and “navigator” were explained to both members of the pairs. The students worked in pairs (one visual and one verbal learner) to discuss and solve novel problems by applying the program flowchart and/or pseudocode in the given tasks. They were to persistently cooperate on the same design, algorithm, coding and testing. From time to time, they were expected to switch roles between the
“driver” and the “navigator”. On the other hand, there were no cooperative learning activities involving the students taught in the DI group. Students of this group were to work individually on the similar programming tasks as to the PP group. During this seven-week of treatment, both groups were to complete two programming assignments in regard to either working as pairs or individual.

Immediately after the treatment, the immediate post-test was administered to the two groups. The delayed post-test was carried out a month later. The students’ programming performance on recall and retention in the basic programming concepts were measured using the CPPT instrument.

Findings

In this study, the pre-test score was used as the covariate to ensure the homogeneity between two participating groups in terms of knowledge status prior to treatment. The MANCOVA (multiple analysis of covariance) was selected to test the research hypotheses as it involved five dependent variables: (1) quality of codes; (2) time taken; (3) errors made; (4) recall; and (5) retention performance.

The results of the analysis are shown in Tables 1-3. Tables 1 and 2 indicate the MANCOVA findings, while Table 3 shows the descriptive statistics. Meanwhile, the graphs revealing the interaction effects between instructional methods and LS preference are illustrated in Figures 3 and 4. The results of MANCOVA analysis in Table 2 clearly reveal no significant difference in recall and retention performance between two treatment groups and visual-verbal LS. This finding shown here involves only between the visual and verbal students taught in the treatment groups. Therefore, it is used to reveal on the interaction effects between instructional methods and students’ LS preference. However, the post hoc test in comparing between the visual and verbal students in both the PP and DI groups, between the visual students in the PP and DI groups, and between the verbal students in both the treatment groups were not the scope of this discussion.

Table 1
MANCOVA Analysis for Dependent Variables in the Two Treatment Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent variables</th>
<th>Degree of freedom (df)</th>
<th>Mean square</th>
<th>Fixation indices (F)</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Quality of Codes Written</td>
<td>1</td>
<td>1,390.45</td>
<td>26.65</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Time Taken in Completion</td>
<td>1</td>
<td>235.03</td>
<td>43.54</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Errors Made in Codes</td>
<td>1</td>
<td>127.70</td>
<td>50.16</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Recall (immediate post-test)</td>
<td>1</td>
<td>5,554.46</td>
<td>48.64</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Retention (delayed post-test)</td>
<td>1</td>
<td>6,102.45</td>
<td>59.02</td>
<td>0.00*</td>
</tr>
<tr>
<td>ILSQ</td>
<td>Recall (immediate post-test)</td>
<td>1</td>
<td>463.75</td>
<td>4.06</td>
<td>0.05*</td>
</tr>
<tr>
<td></td>
<td>Retention (delayed post-test)</td>
<td>1</td>
<td>261.45</td>
<td>2.53</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Note. * at the significant level of 0.05.

Table 2
MANCOVA Results for the Recall and Retention Scores of the Two Treatment Groups and LS

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent variables</th>
<th>Degree of freedom (df)</th>
<th>Mean square</th>
<th>Fixation value (F-value)</th>
<th>Probability value (P-value)</th>
<th>Result</th>
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</thead>
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<tr>
<td>Group</td>
<td>Recall (immediate post-test)</td>
<td>1</td>
<td>7.69</td>
<td>0.07</td>
<td>0.80</td>
<td>Not significant</td>
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<tr>
<td>ILSQ</td>
<td>Retention (delayed post-test)</td>
<td>1</td>
<td>62.56</td>
<td>0.61</td>
<td>0.44</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

Note. * at the significant level of 0.05.
Table 3

Descriptive Statistics of the Dependent Variables for the Two Treatment Groups With Different LSs

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent variables</th>
<th>Group</th>
<th>Mean</th>
<th>Standard deviation (SD)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Quality of codes written</td>
<td>PP</td>
<td>79.81</td>
<td>8.71</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DI</td>
<td>72.08</td>
<td>6.58</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>75.88</td>
<td>8.75</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PP</td>
<td>9.81</td>
<td>1.82</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Time taken in completion</td>
<td>PP</td>
<td>9.81</td>
<td>1.82</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DI</td>
<td>12.99</td>
<td>2.78</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>11.41</td>
<td>2.84</td>
<td>96</td>
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<tr>
<td></td>
<td></td>
<td>PP</td>
<td>3.69</td>
<td>1.65</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Errors made in codes</td>
<td>PP</td>
<td>3.69</td>
<td>1.65</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DI</td>
<td>6.03</td>
<td>1.73</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>4.86</td>
<td>2.10</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Recall (immediate post-test)</td>
<td>PP</td>
<td>77.59</td>
<td>12.39</td>
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<tr>
<td></td>
<td></td>
<td>DI</td>
<td>62.12</td>
<td>9.63</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>69.81</td>
<td>13.79</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Retention (delayed post-test)</td>
<td>PP</td>
<td>67.42</td>
<td>10.19</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DI</td>
<td>51.21</td>
<td>10.78</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>59.26</td>
<td>13.52</td>
<td>96</td>
</tr>
<tr>
<td>ILSQ</td>
<td>Recall (immediate post-test)</td>
<td>Verbal</td>
<td>72.08</td>
<td>12.60</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>67.62</td>
<td>14.43</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Retention (delayed post-test)</td>
<td>Verbal</td>
<td>60.99</td>
<td>12.06</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>57.64</td>
<td>14.58</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>59.26</td>
<td>13.52</td>
<td>96</td>
</tr>
</tbody>
</table>

Figure 3. Interaction effects between instructional method and students’ LSs on recall performance.

Hypothesis 1: There are no significant differences in the quality of codes written between the PP and the DI groups.

The MANCOVA results in Table 1 indicated a statistical significant difference in the quality of codes written between students who received PP, PP and those who received direct instruction, DI ($F = 26.65; p = 0.00$). Therefore, this finding has rejected the first hypothesis. As shown in Table 3, the students who received PP treatment performed significantly better than those of the DI treatment ($\overline{X}_{PP} = 79.81; \overline{X}_{DI} = 72.08$).
Hypothesis 2: There are no significant differences in duration taken between the PP and the DI groups.

The result analysis found a significant difference in the duration taken to complete the programming assignments between the students of PP and DI ($F = 43.54; p = 0.00$). The students who received PP treatment significantly outperformed those who received DI treatment ($\bar{X}_{PP} = 9.81; \bar{X}_{DI} = 12.99$). Thus, the second hypothesis has been rejected.

Hypothesis 3: There are no significant differences in the number of errors made between the PP and the DI groups.

The statistical analysis (see Table 1) also found a significant difference in the number of errors made in the programming assignments between the students taught in the PP and the DI methods ($F = 50.16; p = 0.00; \bar{X}_{PP} = 3.69; \bar{X}_{DI} = 6.03$). The descriptive statistics in Table 3 reveals that students who received PP treatment performed significantly better as compared to those with DI treatment. Therefore, this finding has rejected the third hypothesis.

Hypothesis 4: There are no significant differences in recall and retention between the PP and the DI groups.

The finding indicated that there is a significant difference in recall between the students who received PP and those who received DI ($F = 48.64; p = 0.00$). Similarly, a significant difference in retention performance between both groups of students was shown ($F = 59.02; p = 0.00$). The fourth hypothesis has been rejected as the students taught in the PP method significantly outperformed those taught in the DI method ($\bar{X}_{PP-recall} = 77.59; \bar{X}_{DI-recall} = 62.12; \bar{X}_{PP-retention} = 67.42; \bar{X}_{DI-retention} = 51.21$) for both the recall and retention performance.

Hypothesis 5: There are no significant differences in recall and retention between visual and verbal students in learning programming.

The statistical analysis also found a significant difference in recall performance between visual and verbal students ($F = 4.06; p = 0.05$). The descriptive statistics in Table 3 further indicated that the verbal students performed significantly better than those visual students ($\bar{X}_{visual-recall} = 67.62; \bar{X}_{verbal-recall} = 72.08$). Therefore, this finding has rejected the fifth hypothesis on recall. As for the retention performance, the descriptive statistics (see Table 3) indicated that verbal students obtained somewhat higher mean scores than those visual students.
students (\(\bar{X}_{\text{visual-retention}} = 57.64; \bar{X}_{\text{verbal-retention}} = 60.99\)). However, the MANCOVA results revealed a non-significant difference in performance between both visual and verbal students (\(F = 2.53; p = 0.12; p > 0.05\)). As such hypothesis five on retention has been accepted.

Hypothesis 6: There are no interaction effects between instructional methods and students’ LS preference for recall and retention performance.

The MANCOVA results (see Table 2) of the interaction effects on the two dependent variables were not statistically significant. The interaction graph in Figures 3 and 4 describes the relationship between the instructional methods (PP and DI) and the students LS preference (visual and verbal) across the two groups on recall and retention performance. Both graphs show no interaction effects between the instructional methods and the students’ preferred LS on recall and retention across the two treatment groups (\(F_{\text{recall}} = 0.07; p = 0.80; F_{\text{retention}} = 0.61; p = 0.44\)). Thus, the finding has accepted the sixth hypothesis as no significant effects were observed.

Discussions

This study aimed to investigate the impact of PP instructional method and LS on students’ programming assignments, recall and retention performances during fundamental programming course delivery. Two topics namely “sequence and selection” as a part of the basic programming concepts syllabus are vitally important for first year computer science students who are pursuing programming courses. The interaction effects between the instructional methods and LSs were also analyzed. The research findings indicated that the students taught in the PP method significantly outperformed their peers in the DI group on the course assignments, recall and retention performance. The PP has significantly assisted the students in programming comprehension and problem-solving skills. Likewise, the statistical results showed only a significant difference in recall performance between visual and verbal students in learning programming.

In the programming assignments performance, the findings revealed that the use of PP as cooperative learning approach did significantly improve the quality of codes developed, reduce the duration taken in completing the programming tasks assigned and minimize the number of errors made in codes. In particular, the students in the PP group obtained significantly better scores in programming assignments as compared to their counterparts in the DI group. This cooperative learning structure encourages students to acclimatize themselves to peers’ approaches, perspectives and strategies in solving programming scenarios. Pair activities allow students to brainstorm on the novel problems that stimulate higher cognitive thinking and in turn cultivates “self-troubleshooting” abilities (Xu & Rajlich, 2005; VanDeGrift, 2004). Through peer interaction, the discussions help each member to check for errors and complete the given tasks together in shorter duration with fewer mistakes found in the programming assignments than those working individually in the DI group (Bryant, Romero, & du Boulay, 2007; Kuppuswami & Vivekanandan, 2004). Discussions and explanations in peer learning environment assist the students to reflect upon and elucidate own actions and decisions for deriving the solution, thus, make thinking explicit. Furthermore, these findings on assignment performance have supported previous empirical studies in that the adoption of PP has yielded better quality, fewer defects of codes and shorter development cycles (Bryant, Romero, & du Boulay, 2008; Ballantine & Larres, 2007).

For the recall performance, this finding reported that PP has significantly influenced the students’ immediate recall. In other words, the students in the PP group have achieved higher scores in recall performance than their peers in the DI group. Working in pairs enhances the students’ comprehensions of the
PAIR PROGRAMMING AND LSS IN COMPUTING EDUCATION

programming concepts expression, as these students in the PP group are encouraged to talk. This manner of
learning, allowing them to discuss and self-explain that somehow facilitate problem-solving processes, aid in
making arguments and accepting constructive criticisms, and, thus, develop higher thinking skills. This type of
verbalization has resulted in achieving greater level of understanding and developing clearer “mental model” of
the abstract concepts which are essentially critical to problem-solving (Goel & Kathuria, 2010; Bryant, du
Boulay, & Romero, 2006).

This finding also revealed a significant difference in the students’ retention performances. PP creates
richer social interaction which allows the students in the PP group to clarify uncertainty and identify alternative
and generate solutions with their pair partners. In this pairing approach, students were consistently guided to be
active learners where they were sanctioned to think accountable for self and peers’ learning and to foster better
relationship with others. Hence, these students taught in the PP group shown significant improvement in their
learning efficiency on the retention performance and eventually cultivating the interest towards programming
as compared to those of the DI group when they are persistently cooperate on the given tasks. This leads to
higher order thinking skills which subsequently show positive constructive influence on memory retention.

In LS preference, the findings revealed a significant difference between visual and verbal students in
learning programming for recall performance. In classroom environment, students were taught in auditory
(lecturing) form where visual presentation of auditory information is organized into simple understandable
chunks. This enables verbal students to forms better images of new concepts that thus assist them to easily
digest the conceptual theories during the learning process as compared to visual students. When auditory
information presented in pictorial, diagrammatical and charter forms, visual students may have forgotten it as
their preferred style is in graphical manners. On the other hand, verbal students remember better when they
hear and then say. As such, PP which emphasizes on discussions helps these verbal students effectively by
explaining concepts, theories and approaches used in producing the completed programming tasks to their
partners (Simon & Hanks, 2007; Felder, 2002). However, there was no significant difference in retention
performance between the visual and verbal students during learning process for later information retrieval.

Based on the interaction effects between the two instructional methods and the visual-verbal LSs
dimension, this study revealed no interaction effect in recall and retention between instructional methods
adopted and the students’ LS preference. In other words, visual and verbal students taught in either PP or DI
method benefited equally in programming performance. During the learning process, the effects of the
instructional methods on programming recall and retention did not depend on the different LSs preference of
individual student. This finding supports previous empirical studies that with regard to the preferred style, students somehow change their learning processes from one learning dimension to another when responding to acquiring knowledge (Tie & Irfan Naufal Umar, 2010; Price, 2004; Ayersman, 1993). Perhaps this is the reason why their programming achievements were not affected as these students in both groups were able to comprehend the novel concepts and enhance their problem-solving skills by adapting themselves in different presentation environment. However, the gap in the “Estimated Marginal Means” for the retention performance between visual and verbal students taught in PP group is small. This indicated that the effectiveness of one method particularly depends on the intact group of learners.

Conclusions

The study has emphasized the importance of adopting PP in learning the basic programming concepts in order to solve novel problems. PP has played a significant role in assisting students to develop self-reasoning and solutions on abstract situations, especially for problem-solving. This pairing activity with social interaction element has been used in software industry to enhance programming skills and increase productivities. Thus, in education, PP significantly yields a very positive impact on students’ programming efficiencies and subsequently to achieve greater recall and retention performance. Besides, LS is a predictable stable indicator that could also influence the learning approach of students in perceiving, interacting with and responding to programming concepts. Considering LS components in learning the basic programming construct for classroom delivery may cause significant impact on students’ performance in terms of recall and retention. To reinforce learning, blending both the visual and verbal representation of novel concepts into course deliveries may enhance cognitive knowledge and promote logical thinking skills with respect to programming performance. With deeper understanding on the LS dimensions, it benefits students on the learning outcomes through working with either a heterogeneous or homogeneous pair. For novices, interactive learning through PP creates positive impact on programming comprehension as well as generates fun learning environment to reduce anxiety during coding. It is also suggested that pairing activities to be incorporated into programming classes as this interaction element is vitally crucial in the working environment that the current students are lacking.

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PAIR PROGRAMMING AND LSS IN COMPUTING EDUCATION


Validities of the Signed and Unsigned Lecture Questionnaires

Using the Item Response Theory*

Hideo Hirose
Kyushu Institute of Technology, Fukuoka, Japan

Teachers often raise a question that whether the lecture questionnaires are necessary or not. In this paper, we first show the recent statistical analysis for the official unsigned questionnaire evaluation results took in our faculty. We have found that: (1) the evaluation scores of lectures by students have been rising up year by year, which means that lectures have been improved; and (2) to take a look at the distribution of the evaluation scores as well as the mean value is crucial, which indicates that taking the questionnaires enhances the teaching skills of teachers. In addition to the official questionnaires, the author has been taking the Web-based signed lecture questionnaires to three mathematics subjects for more than five years. Using these stocked data, we have, next, analyzed the relationship between the signed and unsigned lecture questionnaires and found that: (1) Although few unsynchronized relationships between the signed and unsigned evaluation scores are observed, the trends between them are roughly the same; and (2) Detailed analysis for the questionnaires is also important to grasp the student lecture comprehension and satisfaction, via the IRT (item response theory) to investigate whether the official lecture questionnaires in the department and the Web-based signed lecture questionnaires are reliable or not, the questionnaires are reliable.

Keywords: lecture questionnaire, evaluation, IRT (item response theory), signed form (registered form), unsigned form (bearer form), Web-based questionnaire

Introduction

Although the official FD (faculty development) systems are mandatory since 2008 in Japan by the suggestion of MEXT (Ministry of Education, Culture, Sports, Science and Technology), our faculty has been continuing our own FD activities since 2002. The main subject is the lecture questionnaires. Until 2004, the results of the questionnaires are sent to each teacher and the whole statistics are closed. From the second semester in 2004, we have changed the system and each result became open to teachers, students and staffs. At the beginning, we tackled the FD activities aggressively. However, as the day passes, teachers often raise a question that the lecture questionnaires are still necessary or not. The author also began to use the minute paper (Davis, Robert, & Wilson, 1983) and have been using the Web-based lecture questionnaires since 2002. The author feels vaguely that continuing such an activity is still important (Berk, 2006). Thus, the author investigate will here what the continuing FD activities brought us.

First, we show the recent statistical analysis for the official unsigned (bearer) lecture questionnaires took

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Hideo Hirose, Ph.D., professor, Department of Systems Design and Informatics, Kyushu Institute of Technology.
in our faculty. All the statistics regarding the questionnaires are being processed in open. The basic statistical tools are the correlation to know the relationship between the unsigned official lecture questionnaires and Web-based signed (registered) lecture questionnaires.

Next, we analyze the relationship between the signed and unsigned lecture questionnaires in detail using the IRT (item response theory). That is, we investigate whether the official lecture questionnaires in the department and the Web-based signed lecture questionnaires are reliable or not. This analysis will show that it is important to grasp the students’ lecture comprehension and satisfaction.

Trend of Faculty Official Unsigned Lecture Questionnaires

In our faculty, we have two semesters and more than 350 lectures are opened in a semester. The number of students is about 1,500 from freshman to senior. All the teachers are mandatory to carry out the lecture questionnaires at the end of the lectures. Students mark 2, 4, 6, 8 and 10 scores as the evaluation points; the higher, the better. The class sizes are from 10 students to 100 students.

Figure 1 shows the trend of the mean values of the evaluation points for all the lectures since 2004. The results for the first and second semesters are separately dealt with because the types of classes are a bit different from each other. We can see that the evaluation scores of lectures by students have been proportionally rising up year by year, which means that lectures have been improved. The author believes that the decision of score opening to the public made this progress as well as the teacher’s effort.

Trend of Web-Based Lecture Questionnaires

Since 2003, the author has been using the Web-based questionnaires at each lecture time. Thus, 15 times answers are obtained to each student. The questions are that: (1) to urge review of the lecture, the author asked “what the points were”; (2) to know how attractive the lecture, the author asked “what the discoveries were”; (3) to know to what extent students understand the lecture, the author asked “what the questions were”; and (4) to find the technical skill for lectures, the author asked “what the improvements were”. In addition, “the comprehension points” and “the overall satisfactory points” are marked by 1-10 scores; the higher, the better.

Figure 2 shows a trend of the evaluation points to subject A (Statistics and Data Analysis) that scores are the understanding points and the overall points. We can see that: (1) The overall points are a bit larger than the understanding points; (2) There is a high correlation (correlation coefficient value is 0.83) between the overall points and the understanding points; and (3) The points have been rising up year by year similarly to the official unsigned results. This also indicates that continuing the questionnaires may enhance the improvement of the lecture skills.
Figure 2. Trend of the mean evaluation points of a signed lecture questionnaire result.

Figure 3. Comparison between the signed and unsigned questionnaires.

Signed and Unsigned Lecture Questionnaires

The official questionnaires are carried out in unsigned; on the contrary, the Web-based questionnaires are carried out in signed. Are there any differences between the two answers? Although we cannot know the differences to each student, the mean values can be compared with each other. Figure 3 shows the differences between the two evaluation scores to subjects A, B (mathematical computation), and C (probability theory). If
there is a positive correlation between the two evaluation scores, we can use one of either signed or unsigned questionnaires. Although few unsynchronized relationships between the signed and unsigned evaluation scores are observed, the trends between them are roughly the same. These trends are similar to those in Figure 1. The unsigned questionnaires are carried out only one time at the final lecture time and the Web-based signed questionnaires are carried out at every lecture time. Did this cause the difference? Figure 4 indicates a denial to this conjecture. The figure shows the evaluation scores to each lecture time. Fluctuations due to the lecture time are not observed. Thus, we may rely on the use of one of either signed or unsigned questionnaires. We will later discuss the detailed analysis for the unsigned Web-based lecture questionnaires using the IRT.

**Figure 4.** Evaluation scores to each lecture time.

**Distribution of the Evaluation Scores**

We can roughly grasp the trend of evaluation by looking at the mean values of scores for questionnaires. However, we should be cautious and mean value of 5 is obtained when all the students give point 5 at every lecture time, and also obtained when half the students give point 1 at every lecture time and the rest of half gives point 9 at every lecture time. The evaluation distribution reveals the details for the evaluation. Figure 5 shows typical cases for evaluation distribution.

**Figure 5.** Typical cases for evaluation distribution.

Figure 6 shows an actual distribution of subject B. This subject starts in 2005. First, the teacher delivered the high level to students, in 2006, he changed the lecture level much easier and in 2007, he could find the
appropriate lecture level. To know the distribution of the evaluation, scores is important.

Analysis of Lecture Questionnaires Using the IRT

So far, we have investigated the results of the evaluation scores for questionnaires using the basic statistical methods believing that the evaluation scores are true. However, some students may give scores 5 every time, and some may carefully give appropriate scores. We may not believe in the scores for questionnaire as they are. Thus, we have tried to analyze the scores as accurate as possible using the IRT which will be shown in appendix.

Figure 7 shows the score data matrix of Subject A in 2006; column corresponds to lecturing date (lecture time) and line corresponds to student id; dark purple regions mean the absences. We can see that some students give high points at every lecture and some low. With a small number of exceptions, we do not observe the drastic fluctuation during the series of lectures. On the right in the figure, the results of IRT analysis are given. After obtaining the IRT parameters of problem difficulties and students’ abilities, we have rebuilt the score matrix using the success (evaluation) probability equation (1) to every cell in the matrix.

Looking at the two figures, we can see that: (1) There is a similarity between the two matrixes; (2) The unreliable evaluation fluctuations seem to be relaxed; (3) Each student’s evaluation stands out sharply; and (4) There seem little fluctuations among lecture times. Therefore, we may believe in the true scores from the Web-based questionnaires. This assures that the unsigned questionnaires are also reliable due to the similarity between the signed and unsigned questionnaires shown before.

The parameters of problem difficulties are seen in Figure 8 where the curves of item characteristics to each lecture day are shown and the discrimination parameters are all small and similar to each other. Then, we can proceed to use this result with confidence; that is, the results of the lecture questionnaires are reliable.

Figure 9 shows the re-evaluated trend for overall scores using the IRT from 2003 to 2008 fiscal years. Comparing this figure with Figure 2, we can find the sharpness to Figure 9. That is, it is recommended to use the IRT re-evaluation together rather than to use the basic statistics alone.
Figure 7. An example of the evaluation distribution matrix (on the left the raw data are given, on the right the IRT re-evaluated scores are given).

Figure 8. An example of the item characteristic curve.

Concluding Remarks

In this paper, firstly, we have shown the recent statistical analysis results for the official unsigned lecture questionnaire evaluation results taken in our faculty, where we have found that the evaluation scores of lectures by students have been rising up year by year, which means that lectures have been improved. The author believes that the decision of score opening to the public made this progress as well as the teacher’s effort. We have, next, investigated the features for the signed and unsigned questionnaires. We have found the following:
(1) Continuing the questionnaires will improve the lecture skills; (2) Although few unsynchronized relationships between the signed and unsigned evaluation scores are observed, the trends between them are roughly the same; and (3) It is important to know the distribution for the evaluation scores. Lastly, we have analyzed the questionnaire evaluation results using the IRT, where the results of the lecture questionnaires are found to be reliable.

![Histograms showing re-evaluated trend using IRT from 2003 to 2008 fiscal years.](image)

*Figure 9. An example of the re-evaluated trend using the IRT from 2003 to 2008 fiscal years.*

References


VALIDITIES OF THE SIGNED AND UNSIGNED LECTURE QUESTIONNAIRES


**Appendix: Item Response Theory**

For effective evaluation of students’ abilities, the IRT (Hambleton & Swaminathan, 1984; Hambleton, Swaminathan, & Rogers, 1991; Linden & Hambleton, 1996; Baker & Kim, 2004) can be used, and this gives the students’ abilities accurately in addition to the problem difficulty. Adaptive e-learning systems (Mills, Potenza, & Fremer, 2002) and test methods appropriately used may enhance this feature. We have introduced a student self-learning system (Tsukihara, Suzuki, & Hirose, 2008) embedded in the e-learning system, via Moodle (Website, http://moodle.org/), and a new adaptive test method is also proposed recently (Hirose, 2011) to perform the optimal test. Moreover, we have introduced a Web-based students’ evaluation system (Sakumura & Hirose, 2010; Hirose & Sakumura, 2010) and a stress-strength model based ability evaluation system (Sakumura & Hirose, 2010).

In the IRT, we assume a student $i$ having ability takes a problem $j$. If the student is successful in giving the correct answer with probability $P$, such that:

\[
P_j(\theta_i, a_j, b_j) = \frac{1}{1 + \exp\{-1.7a_j(\theta_i - b_j)\}}
\]

where denotes the indicator function such that for success and $\delta = 0$ for failure; $a_j$ and $b_j$ are constants in the logistic function, and they are called the discrimination parameter and the difficulty parameter, respectively; the larger the value of $a_j$, the more discriminating the item is, the larger the value of $b_j$, the more difficult the item is. In a statistical sense in common, $P_j$ in equation (1) is a logistic probability distribution function with unknown parameters $a_j$ and $b_j$; the random variable is $\theta_i$.

However, $a_j$, $b_j$, and $\theta_i$ are all unknown here (see Figure 10).

\[
L = \prod_{i=1}^{N} \prod_{j=1}^{n} P_j(\theta_i, a_j, b_j)^{\delta_{ij}} (1 - P_j(\theta_i, a_j, b_j))^{1-\delta_{ij}}
\]

By maximizing $L$ in equation (2), the maximum likelihood estimates may be obtained. However, it is not easy to obtain the item parameters and the students’ abilities together. There are $2 \times n + N$ unknown parameters to be estimated. Therefore, the item parameters are first estimated by using the marginal likelihood function by eliminating the students’ abilities, such as:
\[ L(U \mid a, b) = \prod_{i=1}^{N} \left[ \int_{-\infty}^{\infty} g(\theta) \prod_{j=1}^{a_i} L(u_{ij} \mid a_j, b_j) d\theta \right] \] ………………… (3)

Where \( g(\theta) \) denotes the ability common to all the students (usually a standard normal distribution) and \( U \) denotes all the patterns of \( u_{ij} \), taking the value of 0 and 1. The EM (estimation maximization) algorithm (Dempster, Laird, & Rubin, 1977) is usually used in such a case (Baker & Kim, 2004).

Then, the students’ abilities are obtained by maximizing the corresponding likelihood function. To circumvent the ill conditions so that all the items are correctly answered or incorrectly answered, the Bayes technique is applied (Baker & Kim, 2004).

To the scores of the lecture questionnaires, we cannot use Equation (2) as it is; that is, we have assumed that \( \delta_{ij} = 0.1 \), the discrete value. Thus, we have modified to allow the continuous value to \( \delta_{ij} \), such as \( 0 \leq \delta_{ij} \leq 1 \). For convenience, the vacant cells are occupied in advance with the mean observed values to each student.

![Figure 10. IRT estimation procedure.](image-url)
Teachers’ Involvement in Implementing the Basic Science and Technology Curriculum of the Nine-Year Basic Education

John Nwanibeze Odili  Sele Sylvester Ebisine, Helen Nwakaife Ajuar
Delta State University, Abraka, Nigeria  College of Education, Warri, Nigeria

The study investigated teachers’ involvement in implementing the basic science and technology curriculum in primary schools in WSLGA (Warri South Local Government Area) of Delta State. It sought to identify the availability of the document in primary schools and teachers’ knowledge of the objectives and activities specified in the curriculum. Interview and questionnaire were used to collect data from headmasters and basic science and technology teachers. The results showed that teachers are not involved in the implementation of the curriculum. This is evident from the fact that primary science teachers do not have knowledge of the curriculum in terms of the objectives and activities. Secondly, the curriculum was not available in most of the schools.

Keywords: teacher, curriculum, implementing, basic education, knowledge

Introduction

Curriculum is a dynamic programme that is expected to address the changing needs and aspirations of any society (Igwebuike, 2008). Nigerian policy-makers and educators recognize the role of science and technology in the achievement of education for all and national development in the present millennium. This has informed an evaluation process that led to the development of the nine-year basic science and technology curriculum of the universal basic education. The curriculum was implemented in September 2008 in primary one in Nigeria. This study is an investigation into the level of implementation of the basic science and technology curriculum.

Background and Literature

In Nigeria, education is perceived as an instrument for achievement of national objectives. According to the National Policy in Education (Federal Republic of Nigeria, 2004), education is an “instrument per excellence” for achievement of national development. This explains the huge amount of money government earmarks for education in its annual budget.

The basic education curriculum is an innovation in Nigerian education system. It was developed by the NERDC (Nigerian Educational Research and Development Council) following a directive it received from the NCE (National Council on Education) in 2005 to restructure and re-align the existing primary and junior secondary school curricula to meet the targets of the nine-year basic education. The features of the nine-year basic education curriculum are as follows: Firstly, it stipulates nine-year continuous basic education structured
as lower Basic Education Curriculum (Primary one to three), Middle Basic Education Curriculum (Primary four to six) and Upper Basic Education Curriculum (JSS (junior secondary school) one to three); Secondly, the overall objectives of the curriculum are to develop interest in science and technology, acquire basic knowledge and skills in science and technology, apply their scientific and technological knowledge and skills to meet societal needs, take advantage of the numerous career opportunities offered by science and technology and become prepared for further studies in science and technology (NERDC, 2007). In addition to these, the curriculum emphasizes the following process skills: enquiry, intellectual, manipulative and societal values. The basic science and technology curriculum for primary school level shares these features.

The provisions of the MDGs (millennium development goals) and the NEEDS (national economic empowerment and development strategies) profoundly influenced the objectives, contents, materials and methods of the nine-year basic education curriculum. According to Gidado (2002) UBE (Universal Basic Education) is aimed at development of life-long education. This is one of the provisions of the MDGs. Gidado (2002), Okam and Bozimo (2002) and Faure (1972) explained life-long education as that which is concerned with helping learners to develop skills, competencies and attitudes which enable him/her to live successfully in the society as well as prepare him/her to assume roles as an adult in future. NEEDS was developed in response to the development challenges of Nigeria. It recognized education as central to the achievement of its goals. It recommended the complete revision of school curriculum “to reflect the dynamism of society and emerge global issues” (National Planning Commission, 2005, p. 36).

Before the introduction of the UBE, the UPE (Universal Primary Education) was in existence. It provided six-year primary education. Junior secondary school was provided as a part of secondary education. Gidado (2002) criticized the UPE on the following grounds. It was elitist and failed to emphasize life-long learning and vocational education. Thus, its products were characterized with unemployment and inability to apply knowledge to their environment. Gidado further noted that another problem with UPE is that its implementation was not evaluated on regular basis. Thus, it became difficult to monitor implementation for possible improvement.

Curriculum evaluation is making value judgment about decision alternatives on the curriculum based on valid data. It is an important stage in curriculum development processes outlined by Wheeler, Nicholl and Curriculum Organization of Nigeria (Igwebuike, 2008). According to Asher (1976), evaluation is an important aspect of every educational innovation in the US. Government laws in US make available funds for the evaluation of educational innovations. Such evaluation is meant to provide answers to pertinent questions that pertain to implementation of different aspects of a programme.

Experts agreed that the teacher is a critical factor in the successful implementation of any educational innovation (Wokocha, 2007; Nwadiani, 1995). They argued that previous policies failed partly because teachers did not possess adequate knowledge about them. This argument was supported by the declaration in the National Policy on Education (2004) that no education system can grow above the quality of its teachers. Nwadiani (2007) stated that among the problems in reform implementation in Nigeria is lack of understanding of the policy. According to Ereh (2005), curriculum implementation consists of two components: the technical and the managerial. The technical component consists of actual development of the curriculum or programme. The managerial component consists of planning for its development. The teacher is central in the task of implementation of any curriculum. His understanding of the curriculum objectives, contents, materials and methods is crucial in his/her ability to implement the curriculum. The nine-year basic education curriculum
which embraced basic science and technology curriculum was implemented in primary one and the basic science component in junior secondary school one respectively in September 2008. Currently, it is in the second year of its implementation. No study to the knowledge of these researchers has evaluated the status of its implementation.

There needs to investigate teachers’ knowledge of the policy as well as evaluate their perceptions of the adequacy and achievability of its contents. Teachers’ knowledge of the policy and their perceptions of the adequacy and achievability of its contents may be influenced by their levels of academic qualification, teaching experience, number of workshops attended and the type of employer. For instance, teachers employed by government are expected to attend workshop under the sponsorship of the state government, perhaps more than their counterparts employed in the private schools.

Methodology

Statement of Problem

The problems of this study are: what is the level of awareness among primary school teachers of the basic science and technology curriculum?; Specifically, are copies of the document available in primary schools, does it guide teachers in lesson preparation, are teachers able to identify the objectives of the curriculum as well as identify teachers and pupils activities for a given topic?; How achievable do they consider these activities?

Purpose of the Study

The purpose of the present study is to ascertain the status of implementation of the basic science and technology curriculum in primary schools. It intends to find out if the curriculum document is available in schools and the extent teachers are conversant with its provisions.

Research Questions

The study sought answer to the following questions:
(1) What percentage of the sampled schools has the basic science and technology curriculum?
(2) What percentage of the teachers is guided by the basic science and technology curriculum in lesson preparation?
(3) What percentage of the teachers can correctly copy the objectives of the basic science and technology curriculum from the document?
(4) What percentage of the teachers can list the teachers’ and pupils’ activities for the topic “exploring your surrounding” from the basic science and technology curriculum?
(5) What percentage of the teachers considered the activities as achievable?

Significance of the Study

First, it will provide information in literature on teachers’ involvement in implementing the basic science and technology curriculum in primary schools. This is likely to stimulate further research in the area.

Secondly, the outcome of the study will provide independent feedback to NERDC on the results of some of the actions taken so far in the implementation of the nine-year basic education programme. Thus, the outcome will serve as basis for further action.

Thirdly, the outcome of the study will guide government and her agencies in identifying areas of intervention in the successful implementation of the nine-year basic education curriculum. This will help to address the existing gaps.

Fourthly, teachers will be sensitized by the outcome of the study to enquire about the nine-year basic
education curriculum. This will improve their awareness on the curriculum.

Scope of the Study

The study was carried out in public primary schools in WSLGA (Warri South Local Government Area) of Delta State. It focused on science and technology curriculum of the nine-year basic education.

Research Design

The descriptive survey design was employed in the investigation. It is capable of collecting data that describe the status of implementation of the basic science and technology curriculum of the nine-year basic education.

Population

Headmasters of primary schools and teachers of primary science and technology in primary one in public primary schools in WSLGA of Delta State constitute the population of the study. According to the statistics from Delta State Ministry of Basic and Secondary Education, there are 52 public primary schools in the area with 52 headmasters and 62 teachers of science and technology.

Sample and Sampling Technique

Data was collected from 26 headmasters and 26 teachers of primary science and technology who were selected from the same school. Random sampling technique was used. Using balloting, 26 primary schools were chosen. The headmasters and teachers of primary science were the subject. The headmasters identified the science and technology teachers in primary one.

Instrument of Data Collection

Oral interview and questionnaire titled teachers’ involvement in implementing basic science and technology curriculum developed by the investigators were employed for data collection. Oral interview was used on the headmaster. Headmasters were asked if they have the basic science and technology curriculum of the nine-year basic education. Where the answer was yes, the headmaster was asked to provide it for sighting. Otherwise, the headmaster was asked to produce the curriculum that the teachers were using for teaching. The questionnaire has 13 items and seeks questions that provide answers to the research questions. It had a reliability coefficient of 0.86. This was an index of the stability of response over-time. An interval of two weeks was used.

Method of Data Collection

Since oral interview was involved, the researchers personally went to the schools to collect the data that were used.

Method of Data Analysis

Descriptive statistic of the percentage type was used to answer the research questions. Percentage was computed for the responses.

Results

The results of data analysis are presented in tables according to the research questions.

Research Question One: What Percentage of the Sampled Schools Have the Nine-Year Basic Science and Technology Curriculum of the Nine-Year Basic Education?

Table 1 provides the data that was used to answer the research question.
Table 1

<table>
<thead>
<tr>
<th>Available</th>
<th>No. of schools</th>
<th>Percentage of schools (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>2</td>
<td>8.00</td>
</tr>
<tr>
<td>No</td>
<td>24</td>
<td>92.00</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 1 reveals that the document is not available in 92.00% of the primary schools in the LGA. Only two of the schools representing 8% have the basic science and technology curriculum of the nine-year basic education.

**Research Question Two: What Percentages of the Teachers Are Guided by the Basic Science and Technology Curriculum in Lesson Preparation?**

Table 2 presents data on teachers’ utilization of the basic science and technology curriculum in lesson preparation.

Table 2

<table>
<thead>
<tr>
<th>Lesson preparation guided by the basic science and technology curriculum</th>
<th>No. of teachers</th>
<th>Percentage of teachers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2 shows that teachers do not use the basic science and technology curriculum in lesson preparation. All the teachers that were sampled said they do not use it.

**Research Question Three: What Percentage of the Teachers Can Correctly Identify and Copy the Objectives of the Basic Science and Technology Curriculum From the Document?**

Table 3

<table>
<thead>
<tr>
<th>Ability to identity and copy the objectives of the basic Science and technology curriculum</th>
<th>No. of teachers</th>
<th>Percentage of teachers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to identify and copy</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Unable to identify and copy</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3 reveals that none of the sampled teachers are able to identify and copy correctly the objectives of the basic science and technology curriculum.

**Research Question Four: What Percentage of the Teachers Can Identify and List the Teachers’ and Pupils’ Activities for the Topic “Exploring Your Surrounding” From the Basic Science and Technology Curriculum?**

Table 4 reveals that none of the sampled teachers was able to identify and copy teachers’ and pupils’ activities for a specified topic in the basic science and technology curriculum.

**Research Question Five: What Percentage of the Teachers Considered the Activities as Achievable?**
Table 4

<table>
<thead>
<tr>
<th>Ability to identify and list teacher’s and pupil’s activities for the topic “exploring your surrounding”</th>
<th>No. of teachers</th>
<th>Percentage of teachers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to identify and copy teacher’s and pupil’s activities</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Unable to identify and copy teacher’s and pupil’s activities</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5

<table>
<thead>
<tr>
<th>Teachers opinion on achievability of teacher’s and pupil’s activities</th>
<th>No. of teachers</th>
<th>Percentage of teachers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to make opinion</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Unable to make opinion</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100</td>
</tr>
</tbody>
</table>

All the teachers sampled were not able to make opinion on whether teacher’s and pupil’s activities of the basic science and technology curriculum are achievable or not.

Discussion

Availability of the Basic Science and Technology Curriculum in Primary Schools

Results from this study revealed that majority of the primary schools in WSLGA of Delta State do not have the basic science and technology curriculum. Only two out of the 26 sampled schools had the document. All the schools were using new national primary school curriculum modules which have been phased out in primary one. This curriculum is different from the new one in the following ways. Firstly, it is organized in a six-year fashion, while the new one is organized in nine-year fashion. Secondly, the old curriculum has science while the new one has science and technology. According to Asher (1976), the curriculum document is an essential element for effective implementation of any new programme. It tells what is expected of the teachers as well as the activities needed to achieve the set objectives. The absence of this document means that the nine-year science and technology curriculum has not taken-off in the majority of the sampled schools.

Utilization of the Basic Science and Technology Curriculum in Primary Schools

The study revealed that primary school teachers are not guided by the basic science and technology curriculum in planning lesson for pupils of primary one. Even in the schools where the document is available teachers’ responses showed that it does not guide them in lesson preparation. It implied that teachers are teaching out of context or expectations of NCE. The nine-year basic science and technology curriculum was developed to meet the millennial needs of primary education in Nigeria (Obioma, 2008; National Planning Commission, 2004). The non-utilization by teachers implies that the goals of EFA (education for all) and the MDGs may not be achieved in Nigeria.

Teachers’ Knowledge of the Basic Science and Technology Curriculum

The study revealed that all the teachers sampled in the study did not have knowledge of the new curriculum. For instance, they were unable to identify the overall objectives of the curriculum and teachers’ and
pupils’ activities needed to teach the topic “Exploring Your Surrounding”. Nwadiani (1995; 2007), Nwokocha (2007) and Ereh (2005) were consistent in the opinion that teachers’ knowledge of the curriculum is very essential for its successful implementation.

Teachers’ lacks of the knowledge of the curriculum mean that the new document cannot be successfully implemented in Nigeria. An important feature of the nine-year basic education curriculum is its emphasis on process skills like enquiry, manipulation, intellectual and societal values. The curriculum presents these skills so as to relate learning including basic science and technology to the immediate environment of the learner. A teacher without knowledge of the curriculum will not be able to present learning in a way as to achieve these skills in pupils.

Conclusions

From this study, it can be concluded that much still needs to be done for effective implementation of the basic science and technology curriculum of the nine-year basic education. The extent at which teachers and head teachers are presently oblivious of the document suggests that a lot of work still needs to be done for these categories of school staff to acquire the necessary knowledge for effective implementation of the curriculum. It is necessary to organize workshop at the local government levels with the aim of acquainting head teachers and subject teachers with the rudiments of the new curriculum.

References

National Policy on Education.
Beyond the Usual Approach of Chemistry Teaching in High Schools*

Chukunoye Enunuwe Ochonogor
University of South Africa, Pretoria, South Africa

There is a huge challenge of high failure rate in physical science across the world and South Africa, in particular at the high school level in recent times. This is in spite of the fact that both the educators and learners go to schools almost on daily basis perhaps doing the same thing in the same way and manner and achieving the same level or less quality results annually. The main objective of this research was to investigate beyond the usual approaches of teaching chemistry by the educators in order to determine ways and practices that can positively influence the educators’ teaching efforts and foster increased pass rate and quality of passes in Physical Sciences. Twenty-seven and 33 learners in their non-randomized intact classes were involved in the control and intervention classes respectively in two different high schools believed to have always underperformed at matriculation examinations in a suburb of Pretoria. The research made use of active learning model and a special form of cooperative learning strategy nick-named “goat and sheep method” with extra activities including animation to teach the experimental class and compared learners’ performances with those of the control group that were taught the usual way. It was found out that upward of 87% of learners in the intervention class showed remarkably improved pass rate in quantity and quality in the post-test. Also, the topics taught became more learner-friendly and the educator achieved higher confidence and proficiency in dealing with the subject. Proper application of the teaching method described in this study enhances chemistry educators’ and learners’ performances anywhere.

Keywords: goat and sheep method, cooperative learning, active learning, animation, redox reactions, electrochemistry

Introduction

There has been a steady decrease since recent years in the pass rate and quality of passes recorded for Physical Sciences (particularly in chemistry) at the FET (Further Education and Training) band as have been evidenced by the matriculation results. Masombuka (2010) noted that about 580,577 matriculants sat for the 2009 examination and almost 230,000 of them failed. It was further observed that a greater preponderance of the failures was those that did mathematics and Physical Sciences. The downward trend became noticeable since 2003 and according to the Minister of Basic Education (2010), 132,988 students achieved above 40% mark for Physical Science in 2009, compared with 144,830 in 2008. The minister, Angie Motshekga blamed

*Acknowledgements: The author whole-heartedly acknowledges the following persons for their various levels of contributions towards the success of this study: Iti Modipane of Steinmulle Engineering Services, Rivonia; Modjadji, Lloyd, University of South Africa, Pretoria; Pretorius, Elizabeth; Mangqase, Ntomhise, University of South Africa, Pretoria; Principals and Physical Science (Chemistry) educators as well as the learners/students of Dr. WF Nkomo High School and Saulridge High School in Atteridgeville, Pretoria.

Chukunoye Enunuwe Ochonogor, Ph.D., FCAI, Institute for Science and Technology Education, University of South Africa.
poor teaching among other factors as the causes of the appalling students’ achievement levels at matriculation examinations. No doubt, some things were being done by the educators all these years and yet, the results have not improved, and rather a steady decline has become the case. Achieving the great need to improve the situation is expected to start at the high school level where a solid foundation should be laid in preparation for university and professional trainings.

The main objective of this research was to investigate beyond the usual approaches of teaching chemistry by the educators. This is in order to determine ways and practices that can positively influence the educators’ teaching efforts and foster increased pass rate and quality of passes in physical sciences in the country. The problem of this study is hinged on the fact that the number of candidates that would like to take up science, medical and engineering courses at the university levels is fast depleting. This is a serious threat to the continuous scientific and industrial growth aspirations of a nation. It is expected that a science educator thinks science teaching as a purposeful means to an important end, student’s learning (Staver, 2007). The problem of this study, therefore, is to identify some approaches and practices that are beyond the usual and which can help the chemistry educator to increase his/her efficiency and achievement of the students.

To ensure that students increase their performances levels and pass rate connotes, the application of teaching strategies can actually promote active learning.

**A Model of Active Learning**

A model of active learning is shown in Figure 1.

![Dee Fink model of active learning](image)

**Explanation of the Components**

Usually, the most traditional teaching consists of little more than having students read a text and listen to a lecture, a very limited and limiting form of dialogue with others. Dee Fink (1999) recommended some steps for implementing the active learning model shown in Figure 1, which include:

1. Expansion of the kinds of learning experiences the educator creates by creating small groups of students and ensuring that they make a decision or answer a given question at a given time, determining ways to engage students in meaningful dialogs about the topic or subject being considered, helping students to directly or vicariously observe what they are learning and making sure that students actually do what they need to learn;
(2) Applying the “power of interaction” by ensuring the use of more of the four components of the model of active learning in the process of teaching to add variety and enhance students’ interest. A proper connection of the components in an interactive manner brings about an increased educational impact both to the teacher and students, thereby granting them the advantage of “power of interaction” (Dee Fink, 1999). For instance, a teacher might use a mixed approach in his/her class by discussing a topic with the learners, assigning the learners to some groups of few membership, giving them individual and group tasks and setting them into action among themselves with him/her moderating the whole exercise. By so doing, the learners and the teacher share from active interaction which eventually promotes active learning;

(3) Providing dialectic between experience and dialogue by creatively setting up dialectic of learning activities in which students share new experiences and engage in a deep and meaningful dialogue. This provides the opportunity for the students to experience significant and meaningful learning that helps them to improve their overall performances especially in chemistry.

It is becoming an open knowledge that the level and type of motivation shown to the learners significantly affects their quality and height of performance in whatever programme they are involved. Barbara (1999) observed that educators can encourage learners to become self-motivated independent learners by helping learners to find personal meaning and value in the materials provided, assigning tasks that are not too easy nor too difficult, making the learners feel that they are valued members of a learning community and creating open and positive atmosphere that can foster learners participatory and effective learning. Such will amount to good everyday teaching practices which eventually enable the learners overcome learner apathy. It further implies that enthusiastic educator with a genuine interest of students and what they learn to enhance students’ motivation, invariably promotes learners’ performances in the subject. The saying that “expectations affect performance” is not a mockery. When learners believe that they can learn something, they show readiness for it irrespective of its level of complexity. A chemistry educator is expected to observe the importance of variety in the reawakening of learners’ involvements in the learning task and their motivations to learn instead of the usual routine talk and chalk method that brings boredom and disgusting feelings in the learners and hence less effective learning taking place. This can be done by incorporating a variety of teaching activities and methods in the subject, such as role playing, discussion and demonstrations, thereby bringing the understanding of the subject matter closer to the learners.

Effective teaching of chemistry like other sciences demands consistency with the nature of scientific inquiry. Project 2061 (2010) observed that sound teaching usually starts with questions and phenomena that are interesting and familiar to learners as they try to find answers to such questions. The approach involves active engagement of learners and use of team approach to ensure frequent group activities in the classroom. It is usual to see scientists and engineers work mostly in groups instead isolated investigators. Learners in their groups come to common understandings and can always inform each other about procedures and meanings of the task at hand. By so doing, there is team responsibility, feedback and communication which become more realistic than the experiences of the usual individualistic textbook-homework-recitation approach. A purposeful and effective teaching of chemistry and science in general should reflect scientific values which culminate in curiosity, creativity, spirit of healthy questioning, promotion of aesthetic values and avoidance of dogmatism among the learners (AAAS (American Association for the Advancement of Science), 1989).

This study made use of a metaphorically-named method of teaching called “goat and sheep instructional method” (Ochonogor & Ajaja, 2005). It is a special form of cooperative instructional teaching style developed
and researched from 2001 to 2004 by this author. As a universal truth, goat and sheep are domestic animals usually kept for similar economic gains, such as meat, cheese, hides and skin products. Characteristically, a goat is known to be a smart and active animal and shows a high rate of comprehension under a short time of conditioning likened to teaching. Goat easily responds to commands and nick-name given to him/her by the owner(s). The animal, sometimes, shows some elements of stubbornness which is comparable to the attitude shown by some more active and intelligent learners at one time or the other excepting a few. On the other hand, the sheep is a good follower of anyone that stands as a leader of the flock and will like to be in groups in most cases. Sheep is less active and perhaps learns slower than the goat. In other words, a sheep is a ready animal to learn from the peers’ irrespective of the condition. A mixed flock of goat and sheep is a mixed multitude of high, middle and low reasoning animals just as it is the case of any class of learners composed of high, middle and low achievers in the school system. The essence of carefully working with “goats” and “sheep” in a common flock is to produce a set of friendly animals that would have gained high level knowledge and intelligence from among them for higher performance at any given time or situation. Under the guidance of the owner (teacher in a classroom situation), the “goats” and “sheep” cooperate with one another, contribute to a common task and consequently share the joy of achievement in terms of cognitive and social development.

The choice of “goat and sheep” method in this study is in support of Staver (2007, p. 8) that effective science teachers believe and act in these ways:

1. Respect and accept the unique perceptions of individual learners;
2. Reflect on and consider learners’ prior knowledge and interests when selecting and using specific strategies and techniques;
3. Believe that all students can and will learn;
4. Create a challenging, but non-threatening learning environment;
5. Commit to the learning and intellectual growth of all learners;
6. View oneself as capable, dependable and generally positive;
7. Believe that one can teach effectively and that effective teaching will lead to positive learning outcomes.

Procedure for the Use of “Goat and Sheep” Method

The procedures for the use of “goat and sheep” method are as follows:

1. The educator is expected to consciously identify the likened “goats and sheep” in the class according to the description given above without actually calling the learners such derogatory names of “goat and sheep”. This should be done by applying his/her experience and knowledge of the learners;

2. The educator clearly states the instructional objectives (D. Johnson & R. Johnson, 1984a, 1984b; Shlomo, 1980, 1994). This enables the educator to design suitable level of knowledge and task expected to pass to the learners. This step further helps the educator appropriate evaluation tool to determine the level of learners’ comprehensions, performances and achievements and hence correctly identify the “goats and sheep” after teaching the topic to the general class;

3. The educator attaches the identified “sheep” to each “goat” to form small learning groups. The size of the groups depends on the number of “goats” available while each “goat” is made to act as the leader of the group and “sheep” as the follower(s);

4. The task for each group is well defined and handed over to the group leader with clear instructions
including: (a) ensure that every member of your group follows and participate in your group task; (b) leave no one in the dark in the process and explain every step taken to the group members as friends. The direction and level of communication expected here is horizontal because they all learners working, explaining, discussing and observing among themselves. Ochonogor and Ajaja (2005) observed the general view that the rate of comprehension of subject contents is higher when students teach themselves after the teacher’s normal programme with them. They learn more and faster as friends and colleagues than the “down-the-line” or “up-the-line” communication direction of the educator to learner and learner to educator respectively; and (c) always say to the members that they all have the opportunity to lead as they work towards achieving the group goal set by the educator;

(5) The educator should avoid grouping all “goats” or all “sheep” together. They should be well mixed up and without prejudice. Heterogeneous group membership should be pursued as much as possible irrespective of race, ethnicity, religion or economic level;

(6) Opportunities to motivate the learners should always be sort and maintained by the educator, especially as it affects chemistry and the other sciences. This could be by ensuring that the expected practical activities in the topic being treated is well taught and demonstrated to the learners particularly the group leaders for onward transmission to others and practice among them. The educator should not hesitate to use improvised materials in the absence of real materials aiming at making the lesson a captivating one. Such improvisation could be in the form of locally available materials, computer simulations and animation;

(7) The educator should integrate guided inquiry approach (Kuhlthau, Mantniotics, & Caspari, 2007) into the process and must not leave the learners to themselves. He/she should join the learners in planning and executing the learning process with an adequate motivation with activities to enable them perform and achieve more and higher than usual;

(8) Consider the approach as capable of promoting deep scientific understanding through teaching that mirrors the nature and characteristics of inquiry in science, the values of science and the body of scientific knowledge (Staver, 2007).

**Methodology**

A mixed method of qualitative and quantitative approaches was adopted in this study with a quasi experimental pre- and post- test non-equivalent control design. Qualitatively, the study conducted a survey across the education districts in Gauteng using interview schedule and questionnaires on identified less-performing high schools chemistry educators and learners. The interview schedule and questionnaire were used to determine some chemistry topics that learners find difficult to comprehend, the present approach used by their teachers and why they find such topics difficult. The initial survey carried out on 30 randomly sampled learners showed 80% (24 of the learners) state that they find redox reactions and electrochemistry in general among others as difficult to comprehend and that physical science (chemistry) teachers teach them by simple lecture method, individual portfolio assignments, with very little or no practical activities. The contents of the questionnaire and interview schedule were based on three research questions.

**Research Questions**

The three research questions are as follows:

(1) What is your most difficult topic to learn in chemistry aspect of physical science?
(2) Why do you experience difficulty in comprehending the topic(s) stated above?
(3) How much of practical work do you undergo with your chemistry educator?

Hypotheses

Two hypotheses were stated for test at $p < 0.05$ as follows:

1. The group taught chemistry with the study teaching approach does not significantly differ in performance from those taught the same topics in the usual conventional way;
2. Learners do not show significant differential levels of motivation in chemistry whether taught with the study teaching approach or the usual conventional way.

The quantitative approach of this study culminated in an intervention programme involving the teaching of redox reactions and electrochemistry in both the experimental and control classes in two different high schools for four weeks. The samples for the intervention classes were naturally composed of intact class membership. The control group had 28 learners while 32 learners were in the experimental group. Each of the two topics was taught for two weeks with special lesson note and work schedule prepared by the author. A pre-test was administered on all the subjects before the commencement of the teaching programme using two educators having similar degree qualifications but differently trained for the purpose of this research by the author. The “goat and sheep” approach was well taught to one of the educators for special application with varieties of activities, while the other was made to teach the same topic but in the usual way to his learners.

The educators used in this study were made to teach redox reactions as a part of chemical equilibrium in the first two weeks and then electrochemical cells and electrolysis as a part of electrochemistry in the last two weeks of the study. This was because a sound knowledge of redox reactions forms a solid foundation for proper understanding of electrochemistry ensuring that proper partial equations and steps for redox reaction calculations introduced in the first two weeks were well applied in the last two weeks. Furthermore, the educator in the experimental school ensured the use of the “goat and sheep” method described in this study and provided necessary supports to the learners. Both educators used in the study taught the same contents to their groups of learners and administered the same pre- and post-tests to them accordingly. The author marked the scripts and analyzed the scores to test the two hypotheses of the study.

Table 1 shows elements in their metallic characters from Li (lithium) through to Au (gold) and the level of reactions with water, steam and dilute acids. Na (sodium), Mg (Magnesium), Aluminium, Zn (Zinc) and Cu (Copper) metals were variously provided and used accordingly in the teaching programme providing extra activities especially in the experimental school.

Example of Redox Reactions

The individual components of these reactions can be discussed as follows (see Figure 2). If a chemical substance causes another substance to be oxidized, it is called the oxidizing agent. In the equation above, $\text{Ag}^+$ is the oxidizing agent, because it has caused $\text{Cu}(s)$ to lose electrons. An oxidant is reduced in the process by a reducing agent. $\text{Cu}(s)$ is, naturally, the reducing agent in this case, as it caused $\text{Ag}^+$ to gain electron.

Figure 3 shows a simple example of steps to calculate electrode potentials and stoichiometric applications in redox and electrochemical reactions. It is a template that any chemistry educator can use to simplify such calculations to the understanding of the learners. The research educator in the experimental school made use of this template as one of the unusual approaches to enhance learners’ performances in the subject.

The research teaching programme covered electrochemical reactions are as follows (see Table 2).
Table 1

Electrochemical Series Showing Reactions With Water, Steam or Acids

<table>
<thead>
<tr>
<th>Metals</th>
<th>Water, Steam, or Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li</td>
<td>(2\text{Li(s)} + 2\text{H}_2\text{O(\ell)} \rightarrow 2\text{LiOH(aq)} + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>K</td>
<td>(2\text{K(s)} + 2\text{H}_2\text{O(\ell)} \rightarrow 2\text{KOH(aq)} + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Ca</td>
<td>(\text{Ca(s)} + 2\text{H}_2\text{O(\ell)} \rightarrow \text{Ca(OH)}_2(\text{s}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Na</td>
<td>(2\text{Na(s)} + 2\text{H}_2\text{O(\ell)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Mg</td>
<td>(\text{Mg(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{Mg(OH)}_2(\text{s}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Al</td>
<td>(2\text{Al(s)} + 6\text{H}_2\text{O(g)} \rightarrow 2\text{Al(OH)}_3(\text{s}) + 3\text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Mn</td>
<td>(\text{Mn(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{Mn(OH)}_2(\text{s}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Zn</td>
<td>(\text{Zn(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{Zn(OH)}_2(\text{s}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Fe</td>
<td>(\text{Fe(s)} + 2\text{H}_2\text{O(g)} \rightarrow \text{Fe(OH)}_2(\text{s}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Ni</td>
<td>(\text{Ni(s)} + 2\text{H}^+(\text{aq}) \rightarrow \text{Ni}^{2+}(\text{aq}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Sn</td>
<td>(\text{Sn(s)} + 2\text{H}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>Pb</td>
<td>(\text{Pb(s)} + 2\text{H}^+(\text{aq}) \rightarrow \text{Pb}^{2+}(\text{aq}) + \text{H}_2(\text{g}))</td>
</tr>
<tr>
<td>H_2</td>
<td>Cannot displace H_2</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td></td>
</tr>
<tr>
<td>Au</td>
<td></td>
</tr>
</tbody>
</table>


Data Analysis, Findings and Discussions

By the way of providing answers to the research questions of this study, the learners’ responses to the interview schedule and questionnaire were analyzed. Question 1 sorts to find out which of the chemistry topics the learners find most difficult to comprehend and 25 (83.3%) out of 30 stated redox reactions and another 23 (76.7%) out of 30 quoted electrochemistry as most difficult among others. According to them, these topics are too abstract as they involve movement of electrons which are not visible. They further added that the involvement of calculations in the topics makes them more difficult. They find it hard to believe the calculations of invisible entities. Question 2 sorts to determine the reasons why the learners find their stated topic(s) most difficult and 21 (70.0%) of the 30 respondents expressed some serious shortcomings about the approach by which they are usually taught by the educators which has always made more of passive listeners in the class. Some 24 (80.0%) of the respondents further noted that they are not always well motivated to study and learn chemistry with full interest. This could be one reason for the obvious and usual poor performance of physical science learners in many countries including South Africa. A learner is more disposed to learn what

---

\[
\text{Co(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2e^- \\
2\text{Ag}^+(\text{aq}) + 2e^- \rightarrow 2\text{Ag(s)} \\
\text{Co(s)} + 2\text{Ag}^+(\text{aq}) + 2e^- \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{Ag(s)} + 2e^- \\
or \\
\text{Co(s)} + 2\text{Ag}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{Ag(s)}
\]

Figure 2. Redox reaction between solid Copper metal and Silver solution.
he/she is interested to learn and interest is greatly influence by level and type of motivation provided to the learner. Twenty-four (80.0%) of the 30 respondents stated that very little or no practical works are done with them in the process of their learning chemistry aspect of physical science. They explained that most of the required facilities and equipment for chemistry learning are foreign in name and physical representations to them. This situation further made chemistry more abstract to the learners than usual. It was based on this obvious universal reason that this study made use of available and improvised materials with additional student-lead activities in the experimental school and compare the outcomes with those from the control school where things were just done in the usual way.

<table>
<thead>
<tr>
<th>Redox Reactions Calculator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of Form</td>
</tr>
<tr>
<td>Calculate the electrode potential for a half-reaction, with inputs being the concentrations and stoichiometric coefficients of the reactants and products and the number of electrons transferred:</td>
</tr>
</tbody>
</table>

**Input Values:**

- Standard Reduction Potentials (volts) = Fe(2+) + 2 e(-) → Fe (s)
- Concentration of Reactant A (molar) = 0.0100 dm³
- Stoichiometric Coefficient of Reactant A = 1
- Concentration of Reactant B (molar) = 0 dm³
- Stoichiometric Coefficient of Reactant B = 0
- Concentration of Product C (molar) = 1 dm³
- Stoichiometric Coefficient of Product C = 1
- Concentration of Product D (molar) = 0 dm³
- Stoichiometric Coefficient of Product D = 0
- Number of electrons transferred (n) = 2

**Results:**

- Standard Potential $E_0$ (from table) = volts
- $E$ (calculated) = volts

**Bottom of Form**

Top of Form

Input Values:

- Potential of first half-reaction (be careful with sign!) =
- Potential of second half-reaction (be careful with sign!) =

**Results:**

- $E$ (calculated) = volts

*Developed by Shodor (1996-2008)*

*Figure 3. Redox Reactions Calculator (in cooperation with the Department of Chemistry, the University of North Carolina at Chapel Hill) bottom of form.*
A t-test statistics was used to test the two hypotheses of this study stated as follows:

1. The group taught chemistry with the study teaching approach does not significantly differ in performance from those taught the same topics in the usual conventional way;

2. Learners do not show significant differential levels of motivation in chemistry whether taught with the study teaching approach or the usual conventional way.

As shown in Table 3, the means score of the learners in the control group form the post-test is 54.57 and the experimental group learners have a mean score of 74.66. Though both groups performed poorly in the pre-test administered on them with mean scores of 41.21 and 41.31 respectively, they showed some gain scores in the post-test. The learners post-test results showed 13 (46.4%) of the 28 in the control group that scored between 60% and 70% while 28 (87.5%) of the 32 in the experimental group scored from 60% to 100%. The percentage gain score is 5.19 and 46.19 respectively. This implies that the teaching approach and the associated predetermined extra activities adopted in the experimental school formed the major source of the high gain scores and hence higher performance of the learners in the experimental group. Table 3 further shows that calculated t-value is 1.7033 and is less than the critical t-value of 3.360 at a degree of freedom (df) of 58 resulting in the rejection of the hypotheses stated above. In other words, the group taught chemistry with the study teaching approach differed significantly in performance from those taught the same topics in the usual way. The learners also showed significantly higher motivation level culminated in their levels of interests and positive attitudes and perceptions towards chemistry than those in the control group.

Implications and Conclusions

The study found out that an upward of 87% of learners in the intervention class showed remarkably improved pass rate in the post-test. The topics taught became more learner-friendly to the learners/students. Furthermore, the learners saw the research-teaching approach very rewarding in terms of social interactions among themselves and with their teacher in the experimental class. In the same vein, the educator achieved higher confidence and proficiency in dealing with the subject with little efforts. The implications of all these are that the approach enhances learners’ participation in the process of teaching and learning, thereby increasing their abilities to achieve more than through the conventional approach. The learners did not only hear the teacher’s/educator’s talk, but took instructions from both the teacher and their fellow learners in their small
groups. The process helped to remove the usual fear and intimidation learners use to have in an environment where the teacher is the almighty. The approach increases the level of understanding and cognitive achievement through the horizontal level of communication among the learners. In addition to increased level of academic achievement, the learners enjoy leadership training by the use of this study’s teaching approach which will eventually help them as future leaders. The approach also enables the teacher/educator to see the need for proper understanding of the learners’ psychology and ensure the development of skills that will positively influence a greater proportion of learners the chemistry/science class.

It is concluded that the “goat and sheep” method as a form of cooperative learning style coupled with appropriate activities including animation as used in this study proved very effective. It is a less expensive approach and yet lends itself to making chemistry lessons more concrete and less ambiguous as improvised materials can easily be used as the case may be.

**Recommendations**

The obvious results shown by this study will require chemistry educators/teacher worldwide to practice the teaching approach. However, researchers are encouraged to use the approach on wider samples for any possible variations or agreements in findings.

**References**


Pretoria.


A Framework for the Development of Mathematical Thinking
With Teacher Trainees: The Case of Continuity of Functions*

Deonarain Brijlall, Aneshkumar Maharaj
University of KwaZulu-Natal, Durban, South Africa

Continuity of functions appears throughout the grades in South African high school (FET (further education and training)) topics as prescribed by the final draft of the Curriculum and Assessment Policy Statement. This article reports on the use of a combined framework of APOS (action-process-object-schema) and DCT (dual coding theories) to analyze data captured in a study which investigated second-year teacher trainees’ understanding of the concept of continuity. The study is qualitative in that it reports on these teacher trainees’ mental constructions of the concept of continuity of single-valued functions, obtained from analysis of their responses to structured activity sheets. The 12 students in this study specialize in the teaching of mathematics for the FET high school curriculum at a South African education faculty. A two-tiered concurrent approach was attempted, one through student-collaborations and the other through an instructional design worksheet, to develop mathematical understandings of the concept of continuity.

Keywords: APOS (action-process-object-schema) theory, three worlds of mathematics, DCT (dual coding theories), single-valued function, continuity

Introduction

Previous studies, for example (Dubinsky, Weller, McDonald, & Brown, 2005) analyzed students’ mathematical learning on an individual basis. This study however analyzed teacher trainees’ understanding, after they carried out investigations first individually and then in a collaborative manner. This is to address the learner-centered approach which underpins Curriculum 2005 (DoE (Department of Education), 2003). We report on an investigation based on the use of activity sheets and group-work to construct the concept of continuity. To collaborate is to work with another or others. In practice, collaborative learning has come to mean students working in pairs or small groups to achieve shared learning goals (Barkley, Cross, & Major, 2005).

A new trend (at least in the European mathematics education community) is using several theories and approaches in a meaningful way (Radford, 2008). In coordinating theories, elements from the different theories are chosen and integrated to investigate a certain research problem. Tall (2004) presented a framework for mathematical thinking based on three worlds of mathematics: (1) the embodied; (2) the symbolic; and (3) formal. It is thought that as new conceptions are compressed into more thinkable concepts, individuals develop

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Deonarain Brijlall, Ph.D., School of Science, Maths and Technology Education, University of KwaZulu-Natal.
Aneshkumar Maharaj, Ph.D., School of Mathematical Sciences, University of KwaZulu-Natal.
through these worlds hierarchically (Tall & Ramos, 2006). The embodied world containing embodied objects (Gray & Tall, 2001) is where we think about the things around us in the physical world, and it includes not only our mental perceptions of the real world objects, but also our internal conceptions that involve visual-spatial imagery (Tall, 2004, p. 30). In order for us to understand this “world of continuous function”, we employed the DCT (dual coding theories) (Paivio, 1986). For the symbolic and formal “worlds of continuity”, we made use of APOS (action-process-object-schema) (Dubinsky & McDonald, 2001). We found it useful to blend the frameworks used by Stewart and Thomas (2009) and Brijlall and Maharaj (2009) to facilitate our analysis in this paper. This led us to the framework given in Figure 1.

Mathematical thinking

- Embodied
- Symbolic
- Formal

Dual coding theory

APOS theory

Figure 1. A modified framework for reflective abstraction.

Maharajh, Brijlall, and Govender (2008) investigated the concept image and the concept definition (Tall & Vinner, 1981) with regard to a deeper understanding of continuity in differential calculus within a Vygotskian paradigm. Vidakovic (1996; 1997) used APOS theory in the context of collaborative learning. Those investigations focused on the differences between group and individual mental constructions of the inverse function concept. Vidakovic (1997) described the construction processes for developing schema (genetic decomposition) of the inverse function. In particular, genetic decompositions which predict the mental constructions are a part of every good APOS based study.

Bezuidenhout (2001) pointed out that misconceptions relating to students’ understandings of the concepts of limit and continuity are impediments to the development of deeper understandings in differential calculus. It seems that many students perform poorly in mathematics because they: (1) are unable to adequately handle information given in symbolic form which represent objects (abstract entities), for example, mathematical expressions, equations and functions; and (2) lack adequate schema or frameworks which help to organize and link different objects (Maharaj, 2005).

Background

Relevance of Study to South African Educators

Following the work by Shulman (1986; 1987) to make academics rethink what was necessary for effective classroom practice, Ball, Thames, and Phelps (2008) made it relevant to content knowledge for mathematics teaching and learning. They have introduced four sub-domains of content knowledge. This paper illustrates each of these sub-domains by features which appear in the questionnaire we employed in the data capture. The four sub-domains of pedagogical knowledge are: (1) CKK (common content knowledge); (2) SCK (specialized content knowledge); (3) KCS (knowledge of content and student); and (4) KCT (knowledge of content and teaching). The knowledge of continuity we found overlaps with the sub-domains (1) and (2). Most functions to be taught in the high, as guided by the NCS (National Curriculum Statement) (DoE, 2003) are continuous.
These functions include \( \{(x; y) \mid y = ax^2 + bx + c\} \), \( \{(x; y) \mid y = mx + c\} \), \( \{(x; y) \mid ax^3 + bx^2 + cx + d\} \), \( \{(x; y) \mid y = \sin x\} \), etc. However, the educators are also faced with the teaching of discontinuous functions like \( \{(x; y) \mid y = \frac{k}{x}, x \neq 0\} \), \( \{(x; y) \mid y = \tan x\} \), \( \{(x; y) \mid y = 2^x\} \) and \( \{(x; y) \mid y = \log x\} \). One of the expectations of the Norms and Standards for Educators (DoE, 1999) is that the educator should be well grounded in the knowledge relevant to the occupational practice. She/he has to have a well-developed understanding of the knowledge appropriate to the specialism. Many mathematics educators find themselves in a position requiring them to implement the syllabus, which includes certain topics they are unfamiliar with. According to Adler (2002), educators with a very limited knowledge of mathematics need to develop a base of mathematical knowledge. They need to relearn mathematics so as to develop conceptual understanding. Taking this into account, we attempted to make certain that trainees’ teachers leave with a base of knowledge relevant to their occupational needs. Mwakapenda (2004) concurred, when stating that a significant concern in school mathematics is learning with understanding of mathematical concepts.

The NCS emphasizes a learner-centered, outcomes-based approach to the teaching of mathematics to achieve the critical and developmental outcomes (DoE, 2003). The following question guided our inquiry into teacher trainees’ understandings in their constructions of the concept of continuity.

How does the graphical representation learning approach facilitate students’ learning process with regard to the construction of the concept of continuity of single-valued functions in differential calculus?

The main intention of the study was to observe how learning of mathematics content, whether effective or not, took place under these circumstances. In order to answer the above research questions, an APOS analysis of the data was conducted.

**Theoretical Framework**

This study was carried out in accordance with a specific framework for research and curriculum development in undergraduate mathematics education advocated by Asiala, Brown, DeVries, Dubinsky, Mathews, and Thomas (1996) which guided our systematic enquiry of how students acquire mathematical knowledge and what instructional interventions contributed to student learning. The framework consists of the following three components: instructional treatment, theoretical analysis and observations and assessment of student learning.

According to Asiala et al. (1996), the functions of APOS theory according to the paradigm illustrated in Figure 2.

![Figure 2. Paradigm: General research programme.](image-url)
In this paradigm, theoretical analysis occurs relative to the researchers’ knowledge of the concept in question and knowledge of the APOS theory. Our study followed the steps of this paradigm. The theoretical analysis served to propose mental constructions (the genetic decomposition) that are most likely responsible for the learning of the continuity concept by the student teachers. The instructional treatment included a collaborative worksheet design and was intended to get the student teachers to make the proposed mental constructions. They were then expected to use the mental constructions to construct an understanding of continuity and hence apply the concept to other situations. Pedagogical strategies that were used including small group-work to complete mathematical tasks, making conjectures using the model proposed by Cangelosi (1996), and a de-emphasis of lecturing in favor of cooperative learning. According to Figure 2, the analysis of data relates to the theoretical analysis in two directions as seen by the double sided arrow. The theoretical analysis provides the questions to be asked of the data which in turn, gives an indication about the effectiveness of the theoretical analysis in terms of mental constructions as well as the mathematics that each student teacher may have learned in the investigation.

**Instructional Treatment**

Visualization plays an important role in learning (Vygotsky, 1978) and in particular, the learning of mathematics. This idea is espoused in the old adage, “a picture is worth a thousand words”. The role of graphs in the teaching of mathematics is complex and has multi-fold dimensions (Brijlall, 1997). In this regard, we adopted the DCT as discussed by Paivio (1986) to motivate our design of the structured worksheet. DCT, a theory of cognition, postulates that visual and verbal information are processed differently and along distinct channels with the human mind creating separate representations for information processed in each channel. Both visual and verbal codes for representing information are used to organize incoming information into knowledge that can be acted upon, stored and retrieved for subsequent use. We designed the worksheet to create graphical representations of continuous and non-continuous functions as visual information. Then both students (apprentices) and tutor (the experienced teacher) engaged collaboratively (Vygotsky, 1978) to provide verbal information, allowing mathematical connections for a deeper conception of continuity to emerge.

According to Paivio (1986), mental images are analogue codes, while the verbal representations are symbolic codes. Analogue codes represent the physical stimuli we observe in our environment and in this study viewed as graphical representations of continuous and non-continuous mathematical functions. These codes are a form of knowledge representation that retains the main perceptual features of what is being observed. Symbolic codes, on the other hand, are a form of knowledge representation chosen to represent something arbitrarily as in the concept definition of continuity in calculus (Tall & Vinner, 1981). Continuity has a pre-formal visual meaning in that it has elements of dynamic movement, being all in one piece, not changing suddenly (either in direction or in formula) and having no holes (Tall & Vinner, 1981; Tall & Bakar, 1992). Supporting evidence comes from research (Vygotsky, 1978) that showed that memory for some verbal information is enhanced if a relevant visual is also presented or if the student can imagine a visual image to go with the verbal information. Verbal information can often be enhanced when paired with a visual image, real or imagined (Anderson, 2005; Anderson & Bower, 1973). This paper also uses collaborative learning from Vygotsky’s theory as a framework for classroom interactions to occur fruitfully (Vygotsky, 1978). Unlike traditional teaching approaches, collaborative learning rewards all individual students participating in the group by explicitly ensuring that all have achieved the intended lesson outcomes (Barkley et al., 2005).
Theoretical Analysis

Piaget, as cited in Brijlall and Maharaj (2009; 2011), expanded and deliberated on the notion of reflective abstraction which refers to the construction of logic-mathematical structures by a learner during the process of cognitive development (Dubinsky, 1991a). Two features of this concept are: (1) It has no absolute beginning but appears at the very earliest ages in the coordination of sensori-motor structures; and (2) It continues on up through higher mathematics to the extent that the entire history of the development of mathematics from antiquity to the present day may be considered as an example of the process of reflective abstraction (Dubinsky, 1991b).

We define the following four concepts that are used in APOS theory of conceptual understanding (Brijlall & Maharaj, 2009; 2011):

1. Action: An action is a repeatable physical or mental manipulation that transforms objects;
2. Process: A process is an action that could take place entirely in the mind;
3. Object: The distinction between a process and an object is drawn by stating that a process becomes an object when it is perceived as an entity upon which actions and processes can be made, and such actions are made in the mind of the learner;
4. Schema: A schema is a more or less coherent collection of cognitive objects and internal processes for manipulating these objects. A schema could aid students to “... understand, deal with, organise, or make sense out of a perceived problem situation” (Dubinsky, 1991a, p. 102).

Observations and Assessment of Student Learning

This followed the instructional treatment and allowed us to gather and analyze data. The data was used in two ways. Firstly, the results of the data analysis were used to test our initial genetic decomposition. Secondly, the data gathered was used to report on the performance of students on mathematical tasks related to the concept of continuity.

Methodology

The structured design of worksheet used an example and non-example approach. In particular, we focused on sorting, reflecting and explaining, generalizing, verifying and refining. The methodology adopted five stages: (1) design of worksheet; (2) facilitation of group-work; (3) capture of written responses; (4) interviews; and (5) analysis and findings. The data collection relied to a large extent on what students could say or write about their learning experiences. The worksheet task was completed over two double periods, each of one and a half hour duration. This included the individual work by students, the discussions in the groups, the group class presentations and the final discussion involving the tutor. The interviews were done with individuals a week later during the free periods involving both the student and tutor. All the interviews were video recorded.

Design of Worksheet

A worksheet was designed in accordance with ideas postulated by a guided problem-solving model suggested by the work of Cangelosi (1996). This work modeled how meaningful mathematics teaching could be planned with the aim of simultaneously addressing the cognitive and affective domains when students solve problems. An interpretation and modification of the guided problem-solving model (Maharaj, 2007) illustrated in Figure 3 has the following three interlinking levels or phases: (1) inductive reasoning: conceptual level processing occurs; (2) inductive and deductive reasoning: Where simple knowledge and knowledge of a
process level occurs; and (3) deductive reasoning: occurring at an application level. This model has also been used in studies involving the learning of concepts in sequences by pre-service students at a South African education faculty by Brijlall and Maharaj (2011) and Maharajh et al. (2008).

In our case, to provide a structured approach in an inductive manner, we implemented the graphical representations as tools to guide the discussion in arriving at the concept definition of continuity. However, we noted that there is always interplay between inductive and deductive reasoning for the different levels. They are continuously present and constantly following each other in mathematical thinking. For example, in an inductive process, very often a preliminary generalising step is reached; the finalisation of an inductive part is the beginning of the deductive part (Maharaj, 2007). Therefore, generalising at each of the different levels implies that the deductive mode of reasoning comes into play.

In creating constraints for the examples and non-examples in the guided worksheets, we implemented the concept of boundaries (Mason & Watson, 2004) that include the characteristics of the existence of function values and limits (see Figures 5 and 6 which show extracts from the worksheet handed to students). For the design of the worksheet, inductive learning activities were used to construct the concept of continuity of functions. This design promoted visualisation and verbalisation. These activities had the following stages within the inductive level: (1) comparison with examples and non-examples and categorising; (2) reflecting and explaining the rationale for categorising; (3) generalising by describing the concept in terms of attributes, that is, what sets examples of the concept apart from non-examples; and (4) verifying and refining the description and definition by testing and refining it. Those stages were chosen since they could be exploited to facilitate the combined framework and contribute to conceptual understanding: action, process, object and schema.

**Group-Work Facilitation**

Twelve second year teacher trainees engaged with the activities individually for approximately 15 to 20 minutes. This was to allow students to make contributions when working in a group setting. The groups were formed by the lecturer using the marks attained in a mathematics education module from the previous semester (Mathematics for Educators 210). The purpose was to ensure that the groups had members with different ability levels, mixed race, mixed gender and different home language. Preston and Robert (2003) noted in this regard that the teacher should carefully group students that can potentially develop in collaboration with more capable persons. When constructing the concept of continuity, they worked in four groups, comprising of three members each. Each group, after discussing and reaching a collective decision, presented their mathematical ideas to the class. The student facilitators reported on the collective ideas or thoughts of their groups. The students were given time limits set by the facilitator to encourage them to focus on the task on hand. The groups were similar in that they had members with a spread of ability levels. At the end of the group
presentations, an intensive classroom discussion including responses from the lecturer led students establish the concept definition of continuity.

**Written Responses**

A guided activity sheet was given to each teacher trainee. When they were in groups, they were required to present the collective group response to the activities. The following five instructions appeared on the worksheets: (1) complete each worksheet on an individual basis; (2) now form groups of three; (3) discuss your findings within the group to reach consensus; (4) write down a collective response and elect a leader to discuss with class; and (5) finally conclude findings as a class with lecturers. This involved the tutor, who is a Ph.D. student and a mathematics lecturer, who clarified, using the worksheets, the mathematically acceptable definition of continuity. The group response worksheets were then collected by the lecturer for analysis of teacher trainees’ constructions of the continuity concept, within a group context.

**Interviews**

The interviews took place after the written responses were analyzed. After categorizing them in Tables 1 and 2, it was then that we employed verification interviews.

**Genetic Decomposition**

Most of the second teacher trainees already had adequate knowledge of existence of limits at this stage in the course. This was verified orally by the lecturer. They also sketched graphs of piecewise functions comprising of linear, quadratic, hyperbolic, semi-circular and absolute-valued functions. This involved an inter-play between graphical illustrations and algebraic notations. The graphical approach provided a visual representation of the algebraic expression of the function. As an example when finding \( \lim_{x \to a} f(x) \) where \( f(x) = 2x^2 \), the students normally proceed using a substitution algorithm without a possible graphical representation of the function. In this regard, when algebraic notations of functions were alone presented, the two-sided approach in the limit concept was not immediately perceived. The students had no formal prior knowledge of the concept of continuity. During the guided problem-solving activity, students were expected to develop the following definition in full sentences, for example, “There is a \( y \)-value for \( x = a \)”, and in notation form as follows: A real single-valued function is continuous at \( x = a \) if: (1) \( f(a) \) exists; (2) \( \lim_{x \to a} f(x) \) exists; and (3) \( f(a) = \lim_{x \to a} f(x) \). So, a function \( f \) is continuous if it is continuous at every point in its domain.

The thorny question of whether a function can be considered discontinuous outside its domain arises. Yes as a global gestalt because there is a hole, but none from the formal definition of a continuous function since continuity only refers to points in the domain.

Based on the above, the following genetic decomposition of the concept of continuity was used to guide our instructional treatment.

As a part of his/her functional schema, the student: (1) has developed a process or object conception of a function; and (2) has developed at least an action conception of graphs of piece-wise functions. As a part of his/her limit schema, the student: (1) has developed a process conception of the limit of a function; (2) has developed at least an action conception of the existence of a limit of function; and (3) recognizes and uses suitable notation and their respective applications to specific situations, and then coordinates previously constructed schemas of a function, limits of functions and appropriate notation to define continuity of a function (see Figure 4).
Analysis and Findings of Results

The following is an extract from the students’ worksheet, labeled Stages A to D. In particular, the mathematical stages are sorting, reflecting and explaining, generalizing, verifying and refining. In Stage A (see Figures 5 and 6), the researcher demarcated the examples and non-examples and the students then compared these distinguishing features, namely, the existence of a function value, the existence of a limit and the equality of the function value with its limit that characterize continuous functions from non-continuous ones.

Extracts Taken From Students’ Worksheet Covering the Four Stages

Stage A: Sorting
The following are examples of graphs of continuous functions.

![Figure 5. Examples of continuous functions.](image1)

![Figure 6. Examples of non-continuous functions.](image2)

Stage B: Reflecting and explaining
After interrogating the above examples and non-examples of graphs of continuous functions, explain why one would categorize them as such;

Stage C: Generalizing the description of continuous functions
Now provide mathematical conditions which a function need satisfy in order for it to be called continuous at \( x = a \);

Stage D: Verifying and refining
Check whether the following functions are continuous or not by using the conditions you have derived in the generalization above:

Example 9 \( f(x) = \begin{cases} x + 1, & \text{if } x \geq 2 \\ x + 4, & \text{if } x < 2 \end{cases} \)

Example 10 \( f(x) = \begin{cases} x^2, & \text{if } x \neq 2 \\ 1, & \text{if } x = 2 \end{cases} \)

Example 11 \( f(x) = \begin{cases} x^3 + 1, & \text{if } x \geq 2 \\ 2x + 5, & \text{if } x < 2 \end{cases} \)
The summary of responses covering the above stages appears in Tables 1 and 2. Table 1 summarizes the four group responses, with the data captured from the video as well as from the group activity sheet. The reflecting and explaining stage and generalizing the concept continuity of functions are tabulated. Characterization of coded categories is as follows: (1) none was used for no response; (2) inadequate codes implied an incorrect or unclear response with features which are not in accordance with our genetic decomposition; (3) partial codes indicated gaps in description where responses had features that resembled our genetic decomposition; and (4) complete codes implied a mathematically correct response in accordance with the concept of continuity.

Table 1

<table>
<thead>
<tr>
<th>Stages</th>
<th>None</th>
<th>Inadequate</th>
<th>Partial</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflecting and explaining</td>
<td>0</td>
<td>2 (groups A and B)</td>
<td>2 (groups C and D)</td>
<td>0</td>
</tr>
<tr>
<td>Generalizing</td>
<td>0</td>
<td>1 (group A)</td>
<td>2 (groups B and D)</td>
<td>1 (group C)</td>
</tr>
</tbody>
</table>

As seen in Table 1, two groups provided inadequate explanations of continuity after they studied the examples and non-examples provided in the guided worksheet. Group B did not consider limits or function values when reflecting and explaining the rationale for categorizing. Their responses given were:

The first four graphs are continuous where the x and y intercepts are included and the graph passes completely through the x and y intercepts. The next four graphs are not since some parts of the graphs are excluded and included. In some cases, there is more than one sketched graph on the same set of axes, indicating that the graph is not continuous.

This has three separate sentences. The first says that the first four graphs are continuous (with some extra observations about intercepts) but does not say the reason why they are continuous. The second sentence, which seems separate from the first, says that the next four are not continuous since some parts are excluded. In other words, there are gaps in the graph contrary to the pre-conception of continuous operations going on smoothly without gaps (Tall & Vinner, 1981). The third sentence says that there is more than one sketched graph in each picture where a picture has a single set of axes. This relates to both the idea of a graph that continues and the long experience that the student will have had of a function given by the same formula that continues through its domain. It is a consequence of how the students have been previously taught functions as being given by a single formula. Thus, all the comments of group B relate to preconceptions of functions as a formula, drawn smoothly and having no gaps. In Dubinsky’s work, a formula is only an action, so the above response from Group B is not even at the process level, since the students possibly think that there are two functions because each piece is defined by a different rule, which suggests an action level response in APOS.

Group B used symbolic language to generalize the definition of continuous functions as confirmed below:

- **Straight line graph**  \( y = mx + c \); parabola  \( ax^2 + bx + c \)

\[
\begin{align*}
\lim_{x \to a} f(x) &= f(a) \\
\lim_{x \to a} f(x) &= \lim_{x \to a} f(x), \text{ if the limit always exists:} \\
\lim_{x \to a} f(x) &= f(a) \\
\text{Point “a” on a domain of } f(x), \ f(a) &= \text{ exist}
\end{align*}
\]

Firstly, this group’s references to the existence of limits occur from their existing schema. It suggests that
these students had an object conception of the existence of a limit of function. They correctly chose suitable notation to illustrate their conception of continuity as an object, since they wrote \( \lim_{x \to a} f(x) = f(a) \). However, two instances of misuse are evident in the second and last lines of their responses. The last line implies that they meant \( f(a) \) exists, so this line should replace the second line. Secondly, there is a clear difference between the group’s concept image in the reflecting and explaining activity with that portrayed during generalizing the definition. In the former activity, the group responses indicate that emphasis was placed on a visual analysis rather than on the algebraic meaning, as it was the case during generalizing. This would imply that at this point the group used only one representation. Thus, the students’ conception of continuity is limited, as it does not include a number of different representations. They did not integrate the symbols that are associated with an algebraic representation of continuity. However, they later resorted to graphical representations as evidenced in the first two functions in Table 2 when provided with examples of piecewise functions in the verifying stage. They provided correct responses and applied sketches of graphs. We suggest that the algebraic statements made in their arguments were not clear in their mental constructions, but when using graphs they had a better sense of what they were arguing. This seems to justify the need for visual representations when trying to understand and make sense of the concept of continuity.

From Table 1, we observe that two out of four groups when reflecting and explaining constructed partial understandings of the concept of continuity. These were:

**Group C:** The continuous functions have no disturbance and their limits exist at all points. Not continuous functions have disturbance (hole) on the graph or either whose limits do not exist at certain points or \( f(x) \) does not exist at some points. There are points which are not on the domain of the function.

**Group D:** One can recognize the first four graphs as continuous only because at point of, for example, \( x \to a \), we have the fixed \( y \)-value which means that at every point of \( x \), there is also a fixed \( y \)-value. For the last four graphs, one can say that they are discontinuous because at some of the \( y \)-values, \( x \) does not exist. This means that at the point of \( x \), there is no unique \( y \)-value.

Group C related continuity to no disturbance, at the same time referring to the existence of limits and points not in the domain, which could relate to an intuitive notion of limit as given in the course earlier. Group D used the intuitive language of limits but asserted that for the last four graphs, for some \( y \)-values, there are no \( x \) values (\( x \) does not exist) again referring to difficulties relating to what they may perceive as holes in the graph. We note that the response of Group C was incomplete, since this group seems to assume that the existence of \( \lim_{x \to a} f(x) \) is a sufficient condition for continuity of the function \( f \) at \( x = a \). It is likely that this option arose from previously learnt concepts that they intended to link now. On the other hand, this misconception could be sourced by an understanding that if \( \lim_{x \to a} f(x) = c \), then \( f(a) = c \) so \( f \) is then continuous at \( x = a \). It seems that this group did adequately reflect on example 7 in Figure 6. As a result, they were unable to satisfy part 6 of our genetic decomposition for continuity, namely then coordinate previously constructed schemas of a function, limits of functions and appropriate notation to define continuity of a function. They were unsuccessful in linking the function schema with the limit schema as illustrated in Figure 4. With reference to the DCT, note that this group could represent visual information by verbal codes since they described points of discontinuity as disturbance.

The response given by Group D may translate to a view that at \( x = a \), \( f(a) = c \) so the limit exists there
because it has a value. This means that Group D incorrectly linked \( f(a) \) or the y-value at \( x = a \) with the limit \( \lim_{x \to a} f(x) \). They did not consider the behavior of a function about points, but they only focused on the value of the function at \( x = a \). This might also explain other shortcomings we come across when teaching calculus. An example of this is that when dealing with procedures, like using substitution to find limits algebraically, students seem to believe that the value of the function at a point (in this case \( x = a \)) is of greater importance, rather than how function values behave around the point. Students in this group were unable to proceed beyond the function schema in our genetic decomposition, as illustrated in Figure 4. They did not realize that the existence of the limit of a function \( f(x) \) as \( x \to a \), does not depend on whether \( f(a) \) is defined. The response clearly shows that Group D employed a correspondence between an interval about an \( x \)-value and an interval about a \( y \)-value. However, they did not use the independent and dependent variables satisfactorily and conclude that \( \lim_{x \to a} f(x) \) and \( f(a) \) must be equal. It is important to help the student(s) move on from colloquial to mathematical insight in a meaningful way as argued by Tall (2003).

Group A’s response when explaining and reflecting was as follows: A continuous function is a function without a break in co-ordinates or a function that goes on without end to either \(-\infty\) or \(+\infty\).

The response above seems to be derived from the colloquial use of the word “continuous” in phrases like “goes on” (meaning that there were no stops). It is observed that Group A viewed the visual representation of a continuous function as a graph in one piece, with domain set of real numbers. This contradicts examples 1, 2 and 4 in Figure 5. With reference to part 5 of our genetic decomposition, this group’s use of symbols was limited to expressing the domain of the function in example 3 of Figure 5. This led to their inadequate generalizations.

Table 2

<table>
<thead>
<tr>
<th>Function</th>
<th>No group response</th>
<th>Incorrect group response</th>
<th>Correct group response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( f(x) = \begin{cases} x + 1, &amp; \text{if } x \geq 2 \ x + 4, &amp; \text{if } x &lt; 2 \end{cases} )</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2. ( f(x) = \begin{cases} x^2, &amp; \text{if } x = 2 \ 1, &amp; \text{if } x = 2 \end{cases} )</td>
<td>0</td>
<td>1 (group A)</td>
<td>3 (groups B, C and D)</td>
</tr>
<tr>
<td>3. ( f(x) = \begin{cases} x^3 + 1, &amp; \text{if } x \geq 2 \ 2x + 5, &amp; \text{if } x &lt; 2 \end{cases} )</td>
<td>0</td>
<td>2 (groups A and D)</td>
<td>2 (groups B and C)</td>
</tr>
</tbody>
</table>

Even though the other three groups offered inadequate or partial explanations when responding to the reflecting and explaining processes in the construction of the concept of continuity, their generalizations displayed evidence of features included in our genetic decomposition of continuity. Group C, in particular, generalized the description of continuity concisely and in accordance with our genetic decomposition. These findings display an interplay existing between graphical and symbolic representations. This was assisted by the guided design using inductive reasoning within the framework of the guided problem-solving teaching model (see Figure 3) and the collaborative learning approach to facilitate the development of the concept of continuity.

In the verifying and refining aspect, three functions were defined in questions 1, 2 and 3 (see Table 2). The majority of students identified the first two functions correctly while the third function was identified correctly by half of the groups. What was pedagogically interesting was that groups A and D could get the first one
correct but not the third. This might be a sign that the students confuse continuity (connectedness of the graph) with differentiability (smoothness of graph). Example 1 has an obvious jump in the middle so it is discontinuous (in a visually coded sense not necessarily symbolically coded). Example 3 is problematic because there is no jump in value, but it has what may be conceived as a discontinuity in the change in the formula. Thus the distinction between examples 1 and 3 is self-evident. The first is clearly discontinuous for any reason one cares to name (visual or formal), the second is mathematically continuous but may “feel” discontinuous visually and dynamically.

Group A tried to reason graphically or geometrically for the first two functions. However, this group of teacher trainees portrayed an inadequate conception of piecewise functions as they considered the second function to be two separate graphs due to the definition provided. Group D supported this notion when their response was “\( f(2) \) does not exist from the second graph in question one”. These groups did not comply with part 2 of our genetic decomposition of continuity. Group D used visual-pictorial processing to check whether functions 1 and 2 were continuous. Group B considered limit existing to be an adequate condition for continuity without investigating whether \( f(x) \) exists or whether it was defined at \( x = 2 \). Therefore, with regard to Figure 4, it seems that this group was unable to link their function schema and limit schema to verify the continuity of the function.

Group A further displayed their inadequate conception of piecewise functions when looking at the second function, by stating that “\( f(x) \) is two graphs”. Their answers were that the one definition of the graph is continuous while the second definition is not continuous. In a separate interview, the representative for group A said “we did not know what to do with \( x = 2 \)”. This implies that the students either did not know how to read/represent the point \((1; 2)\) or that that part of the function was not considered vital in deciding on the continuity of the function. They saw what they believed to be two graphs (actually two formulae), one is \( x^2 \) for \( x \neq 2 \). This clearly “continues” in the sense that it continues off to infinity in both directions. The other is \( f(x) = 1 \) (for \( x \neq 2 \)) which is a single point and so stays in place and does not continue at all. The reason for the distinction in terms of global visual coding is self-evident, and does not involve the mathematical definition of continuity but the colloquial preconception of discontinuity. Group B used both symbolic or numeric and geometric reasoning to give a concise answer to the second function under verifying and refining. Group C used numerical reasoning to arrive at the same concise answer for function 2. Group D, on the other hand, considered the fact that \( f(2) \) did not exist on their graphical representation of function 2 (i.e., open dot on graph), to be a sufficient condition for it not being continuous.

Groups B and C did not use visual or pictorial modeling to answer the third question, but the algebraic manipulations done to find limits and function values were correct. Using this they correctly concluded that the function was continuous. This implies that their schema for continuity satisfies the illustration in Figure 4. Groups A and D, on the other hand, did not use the generalizations they made about continuity earlier to determine whether the third function was continuous or not. Both of these groups reflect on the inequalities in the definition of \( f(x) \) as shown below:

Group D: The use of inequality disturbs movement of our graphs to infinity, therefore, the graphs do not flow (move) freely. There are restrictions; therefore, the function is not continuous. There is an open gap (dot) in the second function in exercise 3.

Group A: not continuous because \( \geq \) and \(<\) means open dot on the graph.
A beautiful expression of dynamic movement is suggested by the response of Group D. The use of inequality disturbs movement, suggesting the changing of the formula disturbs dynamic continuity. The graphs do not flow, so the function is not continuous according to their own personal concept definition. Notice that there are separate statements here. The first two sentences refer generally to disturbing changes of formula. The last sentence refers to the open gap in the third function and also the dot which gives a discontinuity.

Conclusions

The findings of this study showed that some students demonstrated the ability to make use of symbols, verbal and written language, visual models and mental images to construct internal processes as a way of making sense of the concept of continuity of single-valued functions. We also found that our modified theoretical framework was an effective one for this qualitative study and can be considered for future work.

On perceiving functions as mathematical entities, teacher trainees could manipulate these entities, which were understood as a system of operations. The study provided some valuable insights into the mental constructions of teacher trainees with regard to limit of a function and continuity at a point in calculus. These insights should be analyzed and understood keeping in mind the specific methodology that was used. The verifying and refining stages in the construction of the continuity concept required a conceptualization of the concept of continuity as a meaningful mathematical entity. This conceptualization enabled the formulation of a new mathematical idea that can be applied to a wider range of contexts. The responses received in the four stages A to D of the worksheet indicate that most of the teacher trainees were able to construct the concept of continuity and hence were in fact capable of definition-making with some degree of success. This was evident by the overlap in ideas arising from the mental constructions formulated and those that are encapsulated in the definition. The worksheet possibly nurtured their creativity by encouraging and providing opportunities for them to value, share and discuss the new concept freely without fear of being judged or embarrassed by anyone. They were able to assist each other in addressing the common misconceptions at certain stages of the worksheet. This approach offered opportunities for them to collectively recognize previous knowledge, as well as engage in alternative conceptions with group members.

It should be noted that despite accepting that the initial learning of continuity involved the three worlds of mathematical thinking, students at university education faculty are required to be taken to higher levels of learning. We realized that this lesson involved the continuity of a single-valued function at an interior point in the domain of the function and the domain in the case of this worksheet involved the set of real numbers. In follow-up lessons we provided other experiences on continuity to students. We highlight two examples that were discussed in the follow-up tasks.

Investigation of the continuity of the functions is given below:

In example 1, we require students to arrive at an understanding of continuity at end points. They need then to rework condition two of the formal definition arrived at in the worksheet of this study. In example 2, we allow the teacher trainees to experience functions with more than one point of discontinuity.

References

A FRAMEWORK FOR THE DEVELOPMENT OF MATHEMATICAL THINKING


The Elementary Physics in Four Bridge Failures

Bernard J. Feldman
University of Missouri-St. Louis, St. Louis, USA

This paper will describe the failure of four bridges: the I-35W Bridge in Minneapolis, the London Millennium Footbridge, the Nimitz Freeway and the Tacoma Narrows Bridge. There were alternate explanations for the failures of all four bridges. These alternate explanations (engineering design failure vs. maintenance failure, synchronous lateral excitation vs. human balance response, static vs. dynamic mechanism and forced harmonic oscillation vs. aerodynamically induced self-excitation) can all be understood using elementary physics concepts and provide wonderful examples for introductory physics students.

**Keywords**: bridge failure, I-35W Bridge in Minneapolis, London Millennium Footbridge, Nimitz Freeway, Tacoma Narrows Bridge

**Introduction**

This paper will discuss the physics of four bridge failures. These four failures have a number of features in common. All four failures can be understood in terms of elementary physics concepts. Thus, they are all appropriate materials for introductory physics classes at the high school, college or university level. All four bridges’ failures were filmed while they failed or just after they failed and these videos are readily available and can be used to dramatically enhance the classroom presentation. And all four failures have had two different explanations proposed for their failures. How scientists and engineers determined which explanation is correct is also a valuable pedagogical lesson in how science and engineering operate in the real world. The four bridges to be discussed are the I-35W Bridge in Minneapolis, the London Millennium Footbridge, the Nimitz Freeway and the Tacoma Narrows Bridge. The author will discuss them in a reverse chronological order, with the latest failure first.

**I-35W Bridge in Minneapolis**

On Wednesday, August 1, 2007 at 6:05 p.m. (during the evening rush hour), the I-35W Bridge across the Mississippi River in Minneapolis collapsed, killing 13 people and injuring 145. At the time of the collapse, repair work was in progress on the deck of the bridge, resulting in an additional 287 tons of construction materials and equipment being on the bridge deck. A photograph of the I-35W Bridge before the collapse is shown in Figure 1, with an arrow locating the U10 (upper tenth) West junction. After the collapse, two theories were put forth to explain it.

Shortly after the collapse, a number of commentators suggested that lack of maintenance caused the disaster (Flynn, 2009; Kelly, 2008). In particular, Kelly (2008) referred to a photograph taken by the NTSB (National Transportation Safety Board) showing a line of corrosion in the L-11 east gusset plate as evidence in support of her position. In contrast, when the NTSB issued their report, they pointed out that the initial failure...
occurred not at the L-11 east gusset plate, but at the U-10 West gusset plate (Wildey, 2008). This conclusion was supported by video of the collapse showing the collapse starting at that joint and an inspection of the U-10 West gusset plate after the collapse showing clear evidence of it being sheared (Wildey, 2008).

The NTSB also concluded that the failure at the U-10 West gusset plate was due to both the added weight of the construction materials that were parked just above U-10 juncture and the under sizing of the gusset plates. They also concluded that the collapse was not due to a lack of maintenance (NTSB, 2008). Of particular importance was a picture of two gusset plates from the I-35W Bridge taken in 2003 showing significant bowing due to compression stress (see Figure 2). Recalculations of the thickness of the gusset plates needed for the I-35 Bridge confirmed that the gusset plates were under sized—too thin (NTSB, 2008).

One has to wonder why the original calculations for the size of the gusset plates were not checked, what
was going through the engineer’s mind when the engineer took that photograph shown in Figure 2 and why all the construction materials were parked in one place, rather than spread out over the whole bridge. This is an excellent example of how a series of three unlikely errors lead to a tragic conclusion, and if any one of the three had been caught, the tragedy would most likely have been avoided.

**London Millennium Footbridge**

On June 10, 2000, the north-south footbridge across the Thames River opened to public use and immediately experienced an unexpected large lateral oscillations—a wobble—that forced its closing and eventual retrofitting. An excellent video of the wobble can be seen in YouTube (Website, www.youtube.com/watch?v=eAXVa_XWZ8). A picture of the bridge is shown in Figure 3. Synchronous lateral excitation is the explanation commonly given for the wobble by several physicists in the field of nonlinear systems (Dallard et al., 2001; Strogatz, Abrams, McRobie, Eckhardt, & Ott, 2005). Wikipedia’s entry on the Millennium Bridge also reports, “The natural sway motion of people walking caused small sideways oscillations in the bridge, which in turn caused people on the bridge to sway in step, increasing the amplitude of the bridge oscillations and continually reinforcing the effect”.

![Figure 3. Photograph of the London Millennium Footbridge. Source: Peter Visontay.](image)

There are really two questions surrounding the wobble: First, how the oscillation started, and second, how it was amplified. There is consensus on the first question. On average, for every person whose eastern foot takes a step, there will be one person whose western foot takes a step. However, there will be times when more people will use their western (eastern) feet than their eastern (western) feet and this will start the east-west (west-east wobble. From small number statistics, if there are \( N \) people on the bridge, there will be times when there will be \( N^{1/2} \) (standard algebraic notation for the square root of \( N \)) more people using their east (west) foot.
than their west (east) foot. Notice that as \( N \) gets larger, \( N^{1/2} \) gets larger; the minimum wobble amplitude needed for amplification most likely could only have happened when the footbridge was crowded with people, as it was on the opening day.

As for the explanation of the amplification of this wobble, the synchronous lateral excitation model is at best partial and at worst completely incorrect. Let us start with an observation by John Macdonald involving the Clifton Suspension Bridge in Bristol, UK (Macdonald, 2009). The dominant lateral vibration of the Clifton Bridge was at 0.5 Hz. The middle span of the Millennium Bridge also had its first lateral mode at 0.5 Hz, with a second lateral mode of approximately equal amplitude at 1.0 Hz (Dallard et al., 2001). In contrast, the average walker frequency is about 1 Hz. In other words, the average walker took four steps, two with the right foot and two with the left, for every left-right cycle of the first lateral mode of the middle span of the Millennium Bridge. So even if the walkers were in phase with the bridge’s motion, they would not have amplified the bridge’s first lateral mode unless a non-linear mechanism was at work.

An alternate explanation that has nothing to do with synchronous lateral excitation has been suggested first by Chris Barker and in more detail by Macdonald, namely, that the walkers adjusted neither their frequency nor their phase but their balance due to the bridge’s lateral motion (Macdonald, 2009). Macdonald suggested that as a balancing strategy, walkers adjusted the width of their steps in response to the lateral motion of the bridge. For example, if the walker was taking a step with his/her right foot and the bridge was swaying to the right, the walker’s right foot would step farther from his/her left foot and thus further to the right. If the bridge was swaying to the left, the walker’s right foot would step closer to his/her left foot. In this way, the walker’s center of mass motion is in sync with the bridge’s wobble.

As the bridge’s lateral motion increased in amplitude, in some instances, the walkers’ lateral adjustment increased, thus, providing the necessary driving term proportional to the bridge’s lateral motion. That balance response can either amplify or dampen the bridge’s motion, depending on the natural frequency of the bridge and the frequency of the walkers’ steps. Observation of walkers on the London Millennium Footbridge and other lateral swaying bridges and laboratory experiments of walkers on swaying platforms are contradictory (Macdonald, 2009). The wobble is a wonderful example of an unresolved problem, and the author hopes it is presented as such in future physics classes and lectures.

**Nimitz Freeway**

On October 17, 1980, the Loma Prieta earthquake collapsed a portion of the double-deck Nimitz Freeway (the Cypress Street Viaduct on Interstate 880) just south and east of the San Francisco-Oakland Bay Bridge in Oakland, California. Along a 1.4 km north-south stretch, the upper deck of the freeway fell on top of the lower deck of the freeway, killing 42 motorists (see Figure 4). Even though the earthquake occurred during rush hour (5:04 p.m.), traffic was extremely light that day because the third game of the World Series between the Oakland Athletics and the San Francisco Giants was about to begin and many commuters were already at home in front of their television sets. There is no video of the viaduct while it collapsed, but there is an excellent video on the Loma Prieta earthquake that gives a great deal of the engineering analysis of the viaduct after its collapse (Loma Prieta Earthquake of October 1989).

The Loma Prieta earthquake measured 7.1 on the Richter scale. It was the strongest earthquake in the San Francisco Bay Area since the San Francisco earthquake of 1906. Both the earthquake of 1906 and 1989 were caused by the San Andreas Fault line, which runs roughly along the coast of California. By 1989, numerous
accelerometers had been installed around the Bay Area, including one in Emeryville, within one mile of the collapsed Nimmitz Freeway. The ground acceleration at the Emeryville site, shown in Figure 5, lasted about 15 seconds, was primarily in the lateral direction (east-west), roughly oscillatory with a frequency of about 1 Hz and a maximum acceleration of 0.26 g (Governors’ Report of Inquiry on the 1989 Loma Prieta Earthquake, 1990). Even though Emeryville is about 81 km from the earthquake epicenter, the acceleration was amplified because the land originally had been part of the San Francisco Bay, but was filled with soil that had not been compacted. The Nimmitz Freeway only collapsed in areas where it was built on non-compacted bay fill. A very simple and elegant explanation of the dramatically increased acceleration on liquefied soil is given by Carrington (1990).

Figure 4. A section of the collapsed Cypress Street Viaduct of the Nimmitz Freeway. Source: Clift.

Figure 5. Plot of ground east-west acceleration as a function of time recorded at Emeryville during the Loma Prieta earthquake. The vertical axis is acceleration in units of g (9.8 m/s). Source: Governors’ Report of Inquiry on the 1989 Loma Prieta Earthquake, 1990.
A sketch of one-half of the double-deck freeway support structure (called a “bent” by civil engineers) is shown in Figure 6, along with the most common failure mode (Nims et al., 1989). The freeway failed at the hinge between the top of the lower deck and the bottom of the upper deck. Civil engineers considered two possible explanations for this failure—a static mechanism and a dynamic mechanism. From a physics point of view, non-resonant and resonant mechanisms would have been preferable names, but the author will use the original names. The static mechanism asserts that the hinge failed because it could not exert a large enough force to accelerate the upper deck when the lower deck was accelerating up to 0.26 g. The various hinges installed in the Nimitz Freeway were designed to withstand lateral accelerations between 0.10 g and 0.21 g. Since the Loma Prieta earthquake generated accelerations that exceeded these design specifications, the hinges would fail and the upper deck would fall onto the lower deck. However, more recent computer calculations suggest that the hinges could have provided the needed force to accelerate the upper deck to 0.3 g, greater than the maximum acceleration of the lower deck (Bollo et al., 1990).

The dynamic mechanism asserts that the lower deck’s oscillatory motion excited a transverse (east-west) natural mode of the upper deck—a resonance between the driving frequency of the lower deck’s motion and a natural mode of the upper deck—that generated a large enough motion of the upper deck to destroy the hinges (Hough, Friberg, Busby, Field, Jacob, & Borcherdt, 1990). Experiments after the Loma Prieta earthquake on standing portions of the Nimitz Freeway viaduct observed a transverse (east-west) mode at 2.6 Hz and a frequency (Fourier) analysis of Figure 5 established that there was a significant component of the east-west acceleration at 2.6 Hz. Finally, computer calculations supported the theory that the accelerations shown in Figure 5 would generate large enough amplitude in the transverse mode to cause the hinges to fail (Bollo et al., 1990).

The above discussion is a simplification. First, there is some evidence that there was a domino effect, where the collapse of one upper deck section induced the neighboring sections to collapse (Governors’ Report of Inquiry on the 1989 Loma Prieta Earthquake, 1990). When a section of the standing part of the viaduct was
destroyed after the earthquake by damaging one pillar, the domino effect occurred. Second, it should be emphasized that these computer calculations are approximate and their conclusions are open to uncertainty. Finally, even though the cause of this collapse is still not known, the growing consensus among civil engineers does favor the dynamic mechanism.

**Tacoma Narrows Bridge**

On September 22, 1939, the Tacoma Narrows Bridge oscillated and eventually collapsed during a strong wind storm. The behavior of the bridge before and during the collapse was recorded on film and that film shows two very distinct oscillations of the bed of the bridge before its collapse (Fuller, C. R. Lang, & R. H. Lang, 2000). Up until an hour before the collapse of the bridge, the only observed oscillation was a vertical motion of the bridge deck. This vertical oscillation is an example of simple forced harmonic oscillation—the sinusoidal motion of the deck due to an external sinusoidal force (Fuller et al., 2000).

In the last 45 minutes of the life of the Tacoma Narrows Bridge, a new twisting and torsional motion was observed, which had a very large amplitude and was the cause of the bridge’s collapse. A photograph of the bridge executing this torsional mode is shown in Figure 7. Two explanations have been proposed for the cause of this torsional oscillation, simple forced harmonic oscillation and aerodynamically induced self-excitation (aerodynamic flutter). These two explanations have very different characteristics. In forced harmonic oscillation, the deck oscillates at the frequency of the driving force and, in aerodynamically induced self-excitation, the deck oscillates at its natural frequency. In the forced harmonic oscillation model, the deck frequency should change with the wind velocity, since the sinusoidal driving force is caused by vortex shedding by the wind (commonly called a Karman vortex street) and it has a frequency roughly proportional to the wind velocity. In aerodynamically induced self-excitation, the deck frequency is always the natural frequency and does not change with wind velocity. In forced harmonic oscillations, the amplitude of the oscillations will experience a dramatic increase when the natural frequency of the deck is equal to the driving frequency (resonance phenomena). In aerodynamically induced self-excitation, there is no resonance in the amplitude of the deck as a function of the wind velocity, only a gradual increase in amplitude with wind velocity (Farquharson, 1954).

From the video of the collapse, the frequency of the torsional mode does not vary with time, even though the wind speed does vary with time. From wind tunnel results on a 1/50 scale model of the Tacoma Narrows Bridge shown in Figure 8, the amplitude of various deck modes are plotted as a function of wind velocity (Farquharson, 1954). Notice that the NV (vertical modes) of the bridge show resonance behavior, but the NT (torsional modes) do not. Both the video tape and the wind tunnel results provide convincing evidence that the torsional mode of the Tacoma Narrows Bridge is due to aerodynamically induced self-excitation and not simple forced harmonic oscillation.

The really difficult question is the physical mechanism behind aerodynamically induced self-excitation. Billah and Scanlon suggested that the torsional motion of the deck generated a vortex wake that amplified the torsional motion (Billah & Scanlon, 1991); more recently, fluid dynamic computer calculations by Green and Unruh support this suggestion (Green & Unruh, 2006). However, there are other proposed explanations. Lazer and McKenna proposed a nonlinear model where first the wind drove the bridge cables into a high-frequency oscillation and then a non-linear mechanism channeled that energy into the low frequency torsional mode (Peterson, 1990).
Conclusions

It is remarkable that all four of these bridge failures have two explanations and that these explanations can be qualitatively explained to high school, college and university students in their introductory physics classes using basic physics concepts. Also, if the instructor or student wishes to learn more about these four bridge
failures, the author has published papers on all four of these bridge failures presented at a level understandable to both instructors and students (Feldman, 2003; 2004; 2010a; 2010b). The author has used these materials in the author’s introductory classes with great success. Students appreciate seeing physics concepts applied to real life examples and combined with the available video materials. These topics make for excellent lessons, generate enthusiastic questions and cultivate interest in science and engineering.

References


http://www.youtube.com/watch?v=eAXVa_XWZ8
How to Stimulate Students’ Interest in Nuclear Physics?

Stefania Elbanowska-Ciemuchowska, Magdalena Anna Giembicka
University of Warsaw, Warsaw, Poland

Teaching nuclear physics in secondary schools offers us a unique possibility to increase our students’ awareness of the influence that modern science and its achievements have on the everyday life of contemporary people. Students gain an opportunity to learn in what ways the outcome of laboratory research is put to use in such fields as medicine, technology, food conservation and the power industry. At the same time, it is a difficult subject to teach as the physics behind it and the mathematical apparatus required to describe it are very advanced. This part of school curriculum demands abstract thinking and frequently exceeds the students’ cognitive powers. In this paper, we will present some teaching techniques which, while being suitable for teaching nuclear physics in secondary schools, stimulate the students’ interests and engage them in the learning process. While considering traditional methods of teaching physics, which comprise lectures, problem-solving and experiments, as fundamental and thus not to be neglected, we proposed to improve the teaching process by using such techniques as discussions, students’ projects, portfolios, didactic games and excursions.

Keywords: nuclear physics, radiation, teaching methods, active methods, student activity

Introduction

The Polish secondary school curriculum includes an introduction to nuclear physics. The importance of this subject ought not to be underestimated, as it provides students with the knowledge required to formulate their own unbiased opinions on both the threats and advantages brought by the use of radioactive materials. This, in turn, will help them to lead their future lives as conscious citizens. Moreover, teachers ought to keep in mind that the issue of radioactivity can soon become a controversial one in our country, as plans to build a nuclear plant in Żarnowiec are being resurrected.

Additionally, Poland is celebrating the centenary of Marie Curie receiving her second Nobel Prize in 2011. This anniversary and the events it will entail can spur the students’ interests and create many favorable occasions to discuss nuclear physics with them.

Of course, teaching nuclear physics in a secondary school is not an easy task. It is a highly advanced branch of physics, employing a sophisticated mathematical apparatus. To fully describe even such an apparently straightforward phenomenon as the radioactive decay, we need to introduce the exponent and at least some elements of the stochastic calculus. All this, coupled with the scarcity of time at our disposal, means that when talking about nuclear physics, we are frequently compelled to confine ourselves to giving a general description of the processes in question, without recurring to the use of equations and problem-solving, which are a firm anchorage for many students. Coupled with the fact that the subject requires abstract thinking on the
students’ part, this means that this section of knowledge frequently proves too difficult for them to master and their interests tend to stray.

Hence, we present a series of teaching methods that can help to make students interested in nuclear physics and actively involve them in the learning process. For each method, we propose concrete activities (Giembicka, 2009) to be used depending on the occasion and current needs. The activities we proposed can be used either in regular classes or to enliven a meeting of the physics circle. Some can involve the class as a whole or divided into groups, in other cases, one student or a group of students can act as experts taking part in a panel discussion or preparing a presentation for their peers.

We proposed to apply the following techniques in teaching nuclear physics in schools: experiments, discussions, projects, portfolios, didactic games and excursions.

**Experiments**

Experiments have always been an inseparable part of science and one of the most effective ways of acquiring first hand knowledge. Of course, this is true provided that students can take an active part. Depending on the type of school, number of students in class and available equipment, arrangements necessary for students to perform an experiment can pose considerable difficulties. Nevertheless, facing this challenge is well worthwhile, as the benefits are manifold. In the didactics of physics, experiments are a tool to teach self-discipline, organize one’s work and take responsibility for it. They stimulate the students’ powers of observation and inference.

Contrary to common belief, some interesting experiments on radiation can be conducted in a school class. These include:

1. Measuring the characteristics of a Geiger-Müller counter;
2. Comparing the intensity of background radiation outside and inside a building as well as in a well- and badly- ventilated room;
3. Comparing the quantity of radon in the air in different parts of a building.

We shall describe the last of these experiments in more detail.

**Comparing the Quantity of Radon in the Air in Different Parts of a Building**

(Experiment taken from the Physics Laboratory course of the Faculty of Physics, University of Warsaw)

In this experiment, we count the number of α particles from the radioactive decay of radon and its products, a part of a decay chain of uranium-238: \( {}^{222}\text{Ra} \rightarrow {}^{218}\text{Po} \rightarrow {}^{214}\text{Pb} \).

Its didactic aims include:

1. Making students acquainted with the operating principle of a scintillation counter;
2. Comparing the quantity of radon and the products of its decay in different locations in a building.

**Experiment set-up.** The experiment set-up is shown in Figure 1.

![Figure 1. Experiment set-up.](image-url)
**Additional equipment.** To carry out the experiment, we also need a vacuum cleaner, filter, stopwatch and computer software permitting to plot diagrams and to fit a trend line.

**Procedure.** The procedures are as follows:

1. After setting the apparatus, adjust the working voltage so that the input from background radiation amounts to a few counts per minute;
2. Put a fresh filter on the nozzle of the vacuum cleaner and operate the vacuum cleaner for three minutes. Aerosols from the air, including radioactive elements and decay products, will be stopped by the filter;
3. Put the filter in the scintillation counter and register the readings of the pulse counter at minute intervals, starting six minutes after switching on the vacuum cleaner;
4. Repeat procedure in different locations (laboratory, cellar in a basement, attic and open air);
5. Draw your students’ attention to the fact that the pulse registration must always start when the same number of minutes have elapsed since the onset of each operation;
6. Use a computer to plot a diagram basing on the obtained measurements, remembering to adjust the registered numbers so as to eliminate the input from background radiation;
7. Fit trend lines.

![Figure 2](image_url)  
*Figure 2. Comparison between the numbers of counts N(t) registered for the air taken from a cellar and from a storeroom in the building of Faculty of Physics, Warsaw.*

Figure 2 presents the results of an experiment conducted by the authors in the building of Faculty of Physics of the Warsaw University (Giembicka, 2009). The air has been taken from a storeroom and a closed cellar in the basement. Registered number of counts (corrected for the presence of background radiation) has been plotted on the diagram and trend lines extended to the onset of each operation (t = 0).

**Discussions**

A discussion is an exchange of arguments by two or more parties having differing opinions. Its aim is to view an issue from every available standpoint and work out a compromise which is acceptable to all parties.
HOW TO STIMULATE STUDENTS’ INTEREST IN NUCLEAR PHYSICS

(Okoń, 2007).

Taking part in a discussion requires a certain maturity on the part of the students, who have to gather enough information on a given subject to be able to formulate their own opinion and prepare arguments to support it. Participants are obliged to give their statements in a concise and coherent manner, respect their opponents and seek compromise. This type of activity is very useful when working with teenage students who have already mastered some of the art of logical thinking and, at the same time, feel a strong need to voice their opinions. Moreover, making a good appearance in a discussion can be a source of satisfaction for students and enhance their self-respects.

With multiple controversies pertaining to it, the subject of radioactivity is one well suited for discussions. Following is a list of issues which can be discussed during a physics class in a secondary school.

**Topic 1: Radiation—The Threats It Poses and How to Defend Ourselves (Group of Experts)**

This discussion could take the form of “questioning the expert”. The class chooses a group of experts, each of whom is assigned a topic to research and one additional student, who is to prepare a short lecture on radiation. After the lecture is delivered, the discussion is opened to the public who will ask the experts pertaining questions. The discussion could include such topics as (Jaracz, 2001):

1. Sources of radiation (natural and human-made), average annual doses and types of radiation;
2. Biological effect of radiation (depending on exposure time, type and intensity of radiation and the organ in question);
3. Ways of calculating the absorbed and equivalent dose, radiation absorbed in the course of medical diagnosis and therapy and background radiation;
4. The possibility of being exposed to “remnants” of radiation used in food conservation;
5. Radiation protection and types of shielding.

**Topic 2: Should Poland Build a Nuclear Plant? (Decision Tree)**

In this case, we propose the class to be divided into smaller groups. Within these, students can discuss the advantages and disadvantages of nuclear power versus other sources of energy, taking into account such aspects as cost, availability, reliability, environmental contamination, etc. Groups draw their own decision trees, which are then compared and discussed by the class as a whole.

**Topic 3: Nuclear Power as a Source of Future Prosperity (Debate for and Against)**

The disputants are divided in two groups, one of which supports and the other is against the proposed motion. An exchange of arguments takes place justifying each standpoint, following which the discussion is passed to observers (i.e., the rest of the class) who put questions to the disputants. The debate ends with a final voting.

**Topic 4: Energy Sources—Conventional, Renewable, or Nuclear? (Panel Discussion)**

Members of the panel are assigned their roles and given time to gather information and prepare their arguments. The first phase of the discussion takes part among members of the panel, later it is passed to the audience who can put questions to the panel, comment on their statements and voice their own opinions.

Topics 2 to 4 are interchangeable. It is up to the teacher to choose the option best suited to their class, depending on the number of students, their knowledge and general maturity. The topic of these discussions is an interesting and controversial one and will in all probability arouse the students’ interest. Since the knowledge required to take part in such a discussion does not strictly belong to the realm of school physics (i.e.,
one does not need to remember formulas and equations or to solve problems), every student in the class can become a participant.

**Projects**

The project method is an educational technique relying on the students’ individual work. The aim of this method is to produce a tangible result, which in this case will take the form of a presentation on a topic related to nuclear physics. In the course of their work, students decide on the form the outcome of their research should take, on how to achieve the desired final effect and on how to organize their efforts. The teacher’s role is limited to defining (frequently only in general terms) the topic of the project, offering help and encouragement in the process of its execution and later assessing the final result.

The project method supports the students’ individuality and sense of self-dependency, at the same time teaching them to assume responsibility for their own work. In the case of larger projects, an ability to cooperate also becomes a prerequisite, coupled with the skill to coordinate the efforts of many individuals.

The fact that the final outcome, i.e., the presentation itself, is put on public display is also an important psychological factor. Winning the approval of one’s peers can be a source of well-earned pride and enhance the student’s self-respect.

There are a number of topics related to nuclear physics which can constitute a leading theme for a presentation as follows:

(1) Nuclear energy worldwide;
(2) Nuclear power—its history and future;
(3) Practical uses of radioactivity and radioactive isotopes;
(4) Biological effects of radiation;
(5) Nuclear arms;
(6) International Atomic Energy Agency and institutions overseeing nuclear safety in Poland;
(7) Uranium ore deposits in Poland.

The above list is a varied one with regard to the size of the potential outcome. Some of those projects would be better carried out by a group of students and others are well suited for individual work. Likewise, the form of the presentation can vary, depending on the theme and the authors. It can be a lecture prepared by one student or by the members of a physics circle, to be presented to class during lesson. It can also take the form of a series of short oral or multimedia presentation, a poster, or even an exhibition on nuclear physics.

**Portfolio**

In this method, students create their own portfolios on a given subject. Each portfolio contains all the relevant materials a student has managed to gather from different sources. The introduction to nuclear physics is a subject well suited for presentation in the form of a portfolio since:

(1) It constitutes an integral with rather limited contents, which means that even students who have not hitherto carried out projects by themselves will be able to control their work;

(2) Many interesting and controversial topics stem from it—This can encourage students to study the subject in more depth and formulate their own opinions which they can subsequently present in their portfolios;

(3) Many topics are perforce discussed in class in only a very general way, giving ample space for individual research, reflecting a student’s ability to seek out information, their curiosity and concern about the
world around them;

(4) In Poland, this subject is usually taught in the last year of secondary school, in spring, when students are preoccupied with final exams and eager to start their holidays and designing a portfolio is more inspiring and creative than ordinary class work.

The contents of a portfolio evidence a student’s commitment and the effort devoted to their work, therefore, being a good foundation for an assessment of their overall achievements. It is all the more valuable, since it permits the students to display skills which differ from those usually required in their physics class (seen by the students as consisting mainly of ability to memorize a certain amount of data and solve problems). In creating a portfolio, students get an opportunity to prove their diligence and inventiveness as well as an ability to present a piece of work executed with care, accuracy and aesthetic taste. In this way, students who are not perhaps scientifically gifted but conscientious and industrious obtain a chance to improve their marks.

A typical portfolio will contain:

(1) Basic information provided by the teacher during lessons;
(2) Reports on class excursions;
(3) Reports on own experiments;
(4) Results and inferences from discussions, didactic games and presentations given by other students;
(5) Information collected by the student from encyclopedias, books, the Internet, etc.;
(6) Student’s own opinions on a number of issues, such as nuclear power and nuclear arms, multiple uses we have for radioactive isotopes, using carbon dating in scientific research, methods of protecting oneself from the effects of radiation and the lives and achievements of prominent scientist.

It is also important for the teacher to draw the students’ attentions to the fact that a well designed portfolio ought always to contain a list of references and sources.

**Didactic Games**

Games are used in order to achieve predefined didactic aims, therefore, they are considered to be an instrument for teaching (Okoń, 2007). Didactic games are employed by teachers with the aim of putting the school discipline in abeyance and producing a more relaxed atmosphere among the students, thus increasing their activity. The elements of rivalry, existent in every game, also have a very stimulating effect, giving the students an opportunity to present their skills and knowledge and gain an advantage over their peers. By eliminating the tension in class, games create a friendlier environment in which those retiring and self-conscious students can achieve astonishingly good results. Additionally, didactic games are a useful tool for a teacher who desires to assess how well the students have understood a lesson. The easiest method of achieving this aim is to arrange a quiz. We would like to describe two other games designed by the authors with the aim of being used during a lesson on nuclear physics.

**Time Line**

A suitably enlarged timeline is placed in front of the class. The unmatched events (see Figure 3) are printed on cards which can be attached to the time line. By means of discussion, the students decide where to place each of these cards, thus, completing the diagram.

**Decay Chains**

In order to use this game in class, the teacher must prepare a suitable number of diagrams presenting the
four decay chains in which some of the symbols and mass and atomic numbers have been removed (see Figure 4). The class is then divided in pairs and each pair is handed an incomplete diagram. The objective of the game is to fill in the blank spaces with appropriate symbols and numbers.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>1990 the construction of a nuclear plant in Żarnowiec is stopped</td>
</tr>
<tr>
<td>1980</td>
<td>1982 the construction of a nuclear plant in Żarnowiec begins</td>
</tr>
<tr>
<td>1970</td>
<td>1979</td>
</tr>
<tr>
<td>1960</td>
<td>1955 a nuclear-powered submarine (USS Nautilus) embarks on her first voyage</td>
</tr>
<tr>
<td>1950</td>
<td>1952 a thermonuclear bomb is tested (U.S.)</td>
</tr>
<tr>
<td>1949</td>
<td>1949 an atomic clock is build (U.S.)</td>
</tr>
<tr>
<td>1945</td>
<td></td>
</tr>
<tr>
<td>1942</td>
<td></td>
</tr>
<tr>
<td>1940</td>
<td></td>
</tr>
<tr>
<td>1938</td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td>1934 F. Joliot and I. Joliot-Curie discover artificial radioactivity</td>
</tr>
<tr>
<td>1932</td>
<td></td>
</tr>
<tr>
<td>1930</td>
<td></td>
</tr>
<tr>
<td>1920</td>
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<tr>
<td>1919</td>
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<td>1910</td>
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<td>1911</td>
<td></td>
</tr>
<tr>
<td>1903</td>
<td></td>
</tr>
<tr>
<td>1898</td>
<td>1898 M. Curie and P. Curie extract radium from uranium ore</td>
</tr>
<tr>
<td>1896</td>
<td>1896 H. Becquerel discovers radioactivity</td>
</tr>
<tr>
<td>1895</td>
<td>1895 W. Roentgen discovers the X-rays</td>
</tr>
</tbody>
</table>

Figure 3. Time line diagram.
Figure 4. Diagram presenting the decay chain of uranium-235.

The decay chain diagrams can be also used to test the students’ knowledge. In this case, each student receives a card on which a part of a decay chain has been printed (see Figure 5). The students’ task is to supply the elements listed below to fill it in. Supply the missing mass and atomic numbers as well as the type of particle being emitted in each transformation.
the missing mass and atomic numbers as well as the symbols of emitted particles.

$$^{234}_{90}Th \xrightarrow{\beta} \ldots Pa \xrightarrow{\gamma} ^{234}_{92}U \xrightarrow{\gamma} ^{230}_{90}Th \xrightarrow{\alpha} \ldots Ra$$

*Figure 5. A card to be used in a class-test on radioactive decay.*

**Excursions**

Apart from its recreational value, the advantage of an excursion is that it permits to acquire knowledge at first hand. The relaxing of school discipline can have a positive effect on the students’ activities, encouraging them to express their opinions and ask questions (Okoń, 2007).

We propose three types of class outings to be taken into consideration when scheduling lessons on nuclear physics, which is as follows:

1. A visit to an exhibition;
2. A visit to a research institute;
3. A longer field trip.

**Exhibitions**

A museum dedicated to the life of Marie Curie is located in Warsaw. Additionally to housing a permanent exhibition, it holds lectures and screens films, including those related to nuclear physics. Attending such an exhibition can help students understand that scientific discoveries are made by actual people, each with their own history.

**Research Institutes**

The Andrzej Sołtan Institute for Nuclear Physics in Świerk hosts school visits to its research nuclear reactor and holds special lectures on different topics, such as radioactivity, nuclear reactors and the use of radioactive materials in medicine, technology and in everyday life. Students can also visit the laboratories and become acquainted with the apparatus used in actual research. The Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences in Krakow and the Heavy Ion Laboratory of the University of Warsaw also hold lectures for students and stage visits to their laboratories.

According to the National Atomic Energy Agency, there are currently 11 institutions in Poland conducting research in the field of nuclear physics and producing radioactive materials for different purposes. Depending on the location of the school, a visit to one of them can be arranged as a short one-day event or as a part of a longer school trip.

**Field Trips**

It is not commonly known that there are uranium ore deposits in the Świętokrzyskie and Sudety Mountains in Poland. Uranium ore from these deposits was already used before the Second World War by German scientists in their research on radioactivity. Later, uranium ore was mined and processed for the needs of the Soviet atomic bomb project. A part of an old uranium mine in Kowary was also used as an inhalation site in radon therapy.
During a field trip to the location of an old uranium mine, students can gain knowledge on a number of different topics, such as geology and history of the region, ecology (both regions now house National Parks), history of the nuclear arms race, use of radium and radioactive elements in medicine both now and at the beginning of the 20th century.

Old mines in Kowary and Kletno are open to visitors, and in several other towns, it is possible to see the remnants of the now disused uranium mines, many of which have been operated since the Middle Ages, yielding gold, silver, sulphur and iron ores. The fact that some of those mines have for many centuries been considered “unlucky” by the local people can be the starting point for a discussion concerning the biological effects of radiation.

Conclusions

In this paper, we present some techniques which can be used while teaching nuclear physics in secondary schools, comprising experiments, discussions, projects, portfolios, didactic games and class excursions. Each of these methods has been presented by means of specific examples which can be incorporated in any actual schedule, complementing the more traditional forms of teaching. Examples were chosen to assure diversity, offering the teacher a wide range of choice. They can all be easily modified and adapted to the specific needs and circumstances of any school.

Implementing some of the methods presented above can bring manifold advantages both for the teacher and the students, as they:

(1) Permit the students to prove their imagination and inventive skills as well as diligence and thoroughness;

(2) Permit the students to voice and defend their own opinions;

(3) Make the school environment friendlier and more exciting by introducing elements of play and of rivalry among students;

(4) Enhance the students’ commitment to individual study and acquiring knowledge.

These qualities are conducive to stimulating the students’ interest and involvement in the learning process, both matters of crucial importance while teaching nuclear physics, a subject that is difficult both from the academic and the human point of view. The results of research in this field, as well as their practical implementation, have a profound influence on contemporary society, at the same time, being a source of continuing controversy. It is, therefore, of great importance for the school to provide its students with knowledge necessary to formulate measured opinions and be able to defend them. Using active teaching methods can help to achieve this aim.

References

History Teaching in Kenyan Secondary School, for Peace, Reconciliation and National Integration

John Koskey Chang’ach
Moi University, Eldoret, Kenya

“National integration cannot be built by chisel and hammer. It has to grow silently in the minds and hearts of men”.

(Kochhar, 1992)

The main objectives of teaching history and government are: First, to demonstrate an understanding of how people and events of the past has influenced the ways in which people live and behave; Second, to appreciate the need for an importance of mutual responsibility; and Third, to develop a sense of patriotism and national pride. The paper seeks to demonstrate that history is the most important subject for producing a strong feeling of nationalism and integrity of Kenya. Proper teaching of history inspires the students with a sense of patriotism to their motherland. However, currently history and government is compulsory up to form two. Taking Uasin Gishu County as a case in point and basing on the 2009 KCSE (Kenya certificate of secondary education) results of history and government, a large proportion of students drop History and Government in form two. Therefore, this paper argues that the objectives set by the Ministry of Education have not been achieved. It is the contention of this paper that proper teaching of history is one of the best ways of creating a sense of being Kenyan in the students. If history is given a new outlook and orientation, the future will become more fascinating and hopeful. The Kenyan history should give us a panoramic view of the period through which Kenyans have maintained the essentials of their culture. If history is given proper attention, it will promote positive ethnicity and discourage negative ethnicity during this period of post-election peace-building.

Keywords: teaching, history, peace, reconciliation, national integration

Introduction

Most schools of any importance have a science laboratory, upon which a considerable sum of money is spent yearly. For history lesson, few schools supply any apparatus but a textbook and a blackboard. This is a society devoid of any shared feeling of belonging or destiny and a mild strain exposes the deep fissures of ethnicity. Creating a national identity helps to trump politics of ethnic division by persuading the youth not to vote for their ethnic group as happened in 2008 in Kenya, but for the party with politics geared towards national development. Teaching of History and Government to the youth of this country is the only glue that can hold us together in our cultural diversity.

General Objectives for Teaching History and Government

By the end of the course, the learner should be able to (K.I.E (Kenya Institute of Education), 1992):

John Koskey Chang’ach, Ph.D., School of Education, Department of Educational Foundations, Moi University.
HISTORY TEACHING IN KENYAN SECONDARY SCHOOL

(1) Appreciate the importance of history and government;
(2) Demonstrate an understanding of how people and events of the past has influenced the ways in which people live and behave;
(3) Understand the social, economic and political development of certain parts of the world and relate to the history of Kenya;
(4) Derive through the study of history an interest in further learning;
(5) Develop the capacity for critical analysis of historical data;
(6) Appreciate the need for an importance of mutual responsibility;
(7) Develop a sense of patriotism and national pride through participation in various development activities in the country.

The Contemporary Situation

Table 2 shows the number of 2009 KCSE (Kenya certificate of secondary education) candidates and those who did history and government in Uasin Gishu County (Eldoret East, Eldoret West and Wareng districts).

<table>
<thead>
<tr>
<th>District</th>
<th>Total number of KCSE candidates</th>
<th>Total number of candidates in history and government</th>
<th>Percentages (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eldoret East</td>
<td>2,117</td>
<td>1,220</td>
<td>57.63</td>
</tr>
<tr>
<td>Eldoret West</td>
<td>2,865</td>
<td>1,675</td>
<td>58.46</td>
</tr>
<tr>
<td>Wareng</td>
<td>1,833</td>
<td>1,054</td>
<td>57.50</td>
</tr>
</tbody>
</table>

Note. Source: KNEC (Kenya National Examination Council).

The percentages show that many students have only done history and government up to form one or two depending on the school. Therefore, many of them do not know about the history of their own country. The information clearly indicates that the objectives set have not been achieved. This is a wake-up call to the policy makers in the Ministry of Education to look into the entire curriculum.

The situation at the national level also indicates that a good percentage of young people finish high school with very little knowledge about their country as indicated in Table 2.

<table>
<thead>
<tr>
<th>Total number of 2009 KCSE candidates in Kenya</th>
<th>Total number of 2009 KCSE candidates in history and government</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>337,404</td>
<td>212,095</td>
<td>62.861</td>
</tr>
</tbody>
</table>

Note. Source: KNEC.

In 2009, 125,309 candidates finished form four without demonstrating an understanding of how people and events of the past have influenced the way in which people live and behave, appreciating the need for mutual responsibility and developing a sense of patriotism and national pride. The argument in this paper is that 37% of Kenyan youth completing form four is not an insignificant figure. This calls for an urgent attention by all the stakeholders interested in the youth of this country.

Education and Nation Building

The primary goal of education in any society is to harness and develop the talents and human potentialities
of every individual so that he/she can fulfill his/her moral, intellectual and material needs and contribute to the
general well-being, survival and development of that society. Thus, education, in all its facets, is a life-long
process through which an individual acquires knowledge and skills that can enable him/her to understand and
adapt to an ever-changing physical and social environment. It has been observed that the collective
potentialities of people in the form of knowledge, skills, values and attitudes are the main assets of a nation in
its development (Namaswa, 2000).

On the other hand, nation-building is a process of reconstructing a society’s shattered and economy as to
reflect the socio-economic and political needs of the people, who constitute that political community. After the
recent post-election violence in Kenya, the government has to take urgent steps to rebuild a new Kenyan nation
with a national outlook and identify. To achieve this, education is seen as the only instrument that can be used
to bring about this new nation.

**What Is the Use of History?**

Nobody seems to have any answer. This paper will show that there is a completely satisfactory answer to
the question, an overwhelming case for the study of history. History is about human society, its story and how
it has come to be what it is, knowing what societies have been like in the past and their evolution will give the
cue to the factors that operate in them, the currents and forces that move them and the motives and conflicts,
both general and personal, that shape events. It is a study dealing with human nature all the time. It is the only
discipline that enables one to understand public events, affairs and trends of the time. Sir Charles Firth tells us,
“Not only is history a branch of learning to be studied for its own sake, but a kind of knowledge which is useful
to men in daily life to make men wise” (as cited in Rowse, 1963).

History, as a subject of study, rids one of illusions to grow up and become adult. History is as fundamental
as our life. It is through what we know of history that we are delivered from our bonds.

**History and Education**

It is evident that history is a subject of great educational value. As our historical reading widens and our
judgment of events matures, we find fine achievements, sad mistakes and much humdrum endurance
everywhere in the human record, and we come to see the histories of different peoples, with their contacts of
peace and war, their currents of mutual influence and reaction, their parallels and affiliations and their
similarities and contrasts. All as a part of one history (Moi, 1986) from that viewpoint, history is the most
synoptic and unifying of all studies. But it implies and demands education, fortunately, it also provides it. The
process is a dual one. History is a panorama of character in action in every conceivable situation, because it
widens indefinitely the circle of our acquaintances, provides abundant material for the analysis of motives and
gives opportunity for cultivating restraint, tolerance and charity in the judgment of unpleasant ones. Therefore,
this paper states an extremely strong case for the study of history in Kenyan secondary schools, and if possible,
makes it a compulsory subject.

**The Pivotal Position of History Teacher**

The laboratory of history is the world we move about in. And it is desirable that teachers of history should
be cultivated by people, capable of introducing their students to the diversity and richness, the memories and
associations of the world immediately about them. It is a fact that it is the teacher who can make history a living,
interesting and useful subject. The story of man has to be interpreted in as objective and sincere a manner as
possible only if the teacher is equipped with some essential qualities, such as mastery of the subject and techniques. The teacher of history must have the power of realizing and the dead past in the living present, and in fact, have a touch of imagination as well as a vastly large amount of positive knowledge. In the hands of an inspired teacher, history, like any other subject, can become a means of real education. Therefore, this paper advocates for proper training of history teachers and the continued professional growth of the teachers.

**History Teaching and National Integration**

Kenya today, as never before Kenyans, must stand as one nation. The post-election violence which led to negative ethnicity posed a serious challenge. Unless steps are taken to create an emotional upsurge amongst the people for national unity, the fissiparous tendencies in the people may lead to serious consequences.

No nation can flourish or exist long without the unity of spirit (Ayang-Nyongo, 1993). The choice before us is unity or destruction. We must, therefore, hold together as a single, compact and undivided nation, or we will fall to pieces. We must achieve and consolidate the unity of Kenya. Without it nothing worthwhile can be accomplished. If we wish to retain our hard won freedom, national emotional integration has to be our natural tune, because once the people are integrated emotionally, they start feeling as one nation, and there will not be any further difficulty to national solidarity. National emotional integration is, therefore, the greatest need of the hour.

**What is national emotional integration?** National integration is a feeling that binds the citizens of a country. The job is to inculcate knowledge of the country, pride in it and respect for the best in the national, environment, aspirations, traditions and a wish to improve our country. National integration aims at fostering increasing respect and affection for those belonging to other cultural and ethnic groups. It creates and strengthens the people attributes of patriotism and national pride. National integration can be unity in diversity. The feeling of overall oneness of the nation results in fostering national integration (Ogot, 1996).

Emotional integration is the intellectual integration which education can accomplish. An emotionally integrated community gives the people the feeling of espousing a common cause and gives up loyalty to ethnic groups. It gives the progressive realization that there can be similarities among differences.

**Why is national emotional integration?** We must strive for promoting national emotional integration among our students for the following reasons: (1) To preserve unity in diversity—Kenya is a land full of diversities. There are differences in the ways of life of the people in different parts of the country. There is also a common bond of a common culture, which binds the individuals into a single nation. This unity in diversity has to be emphasized; (2) To ensure rapid social, economic and educational progress—Kenya can progress in the various fields if it is united; (3) To enrich the cultural life of the nation by developing the culture of the various groups as a part of a single nation; (4) To check fissiparous tendencies; and (5) To ensure security from internal danger and external aggression.

**Role of education in national emotional integration.** Education, properly oriented in respect of the knowledge which it imparts, the capacity for thinking which it develops, the training of emotions which it undertakes and the practical activities which it organizes, can be a potent instrument in the making of the people of the country an integrated nation. In order to bring about national integration in the country, our secondary schools need to make a deliberate effort to reorient their educational programmes to educate the students on the virtues of culture and civilization. This reorientation is required under various aspects of school programmes like the aims of education, the content, the teaching process, text-books, and the research and so
on. Through content, methods and devices education should develop the following:

1. The understanding that Kenya is one nation;
2. The understanding that there is a basic unity underlying the diversities in Kenya’s culture;
3. A legitimate pride in one’s own culture and also an appreciation for the culture of others;
4. An understanding that throughout Kenya’s history borrowing of others’ culture has constantly taken place;
5. An appreciation that the different parts of the country are economically interdependent and that the country faces many common problems;
6. That the country’s social and economic progress depends upon the cooperation of all parts and all people of Kenya and also upon the balanced development of every part of the country;
7. A feeling that the cooperation and effort of every citizen is essential for the attainment of the country’s ideals;
8. Respect for other individuals and their beliefs, irrespective of the place of their birth, religion or language;
9. An appreciation of steps the country has taken and is taking towards the attainment of national integration;
10. A skill to subordinate group or local loyalties to national loyalties;
11. An understanding that tradition and history have to be tackled and interpreted in an objective way so as to serve as a sound foundation for a growing society.

History and national integration. History is the most important school subject for producing a strong feeling of nationalism and integrity of Kenya. History must inspire its students with love of the motherland. It should be taught as a story of mankind. The Kenyan history should give us a panoramic view of the long period through which we have maintained the essentials of our culture. The teaching of history in secondary schools should be given a new orientation and outlook in the following areas: history content, history teaching, text-books and illustrations used in teaching, each of which may be used as a source of patriotic influence.

The paper argues that Kenyan history should be presented as a coherent whole in an objective way and emphasis should be on cultural synthesis.

Conclusions

This study is not against the teaching of science in schools, which is obviously essential. But there can be too much of it, especially if it makes exclusive claims or disconsiders of the humanities. There is rather an unthinking bias in favor of science in the schools, and nowadays, people assume that it must be the right thing, since this is the scientific age and it obviously leads to certain careers in industry and elsewhere, but do not consider whether it provides a general education for the mind. National emotional integration is the greatest need of the hour. History is the most important school subject for the purpose of producing a strong sentiment of national integration. To enable history play its part, it needs to be rewritten in an unprejudiced form. Its content should be reoriented, and textbooks should be purged of all that is anti-national. The teacher should be extra careful in handling the situation of conflict.

Recommendations

A number of techniques could be used for promoting national emotional integration:
(1) Make the teaching of history and government compulsory from Forms one to four and even in institutions of higher learning;

(2) History should be made a special subject just like language and sciences;

(3) To motivate the history teachers, the employer should give them study leave with pay to pursue further learning, just like in other disciplines;

(4) The misleading notion that humanities are a specialty for the ladies should be discouraged;

(5) Singing of the national anthem and other patriotic songs can go along with the way in creating in the mind of the young a rightful pride of their country;

(6) Symposia, debates and discussions on topics of secular nature, besides increasing the thinking capacity of the students, will widen their mental horizon about the diversification of their country;

(7) Public awareness or education is necessary for the re-orientation of human resource development efforts. This type of education should include the following special programmes: peace education, human right education and environmental education. This education should develop the attitudes which could conscientise and empower them to appreciate and cope with social and cultural diversities. The various concepts, such as interdependence, social justice, equality, equity, conflict resolution, ethnicity and democracy, and human rights should form the agenda for the campaign of both educators and politicians. The citizens should be taught the sources and causes of conflicts as well as the skills of conflict-resolution and how to promote peace at all levels. The public should be sensitized on the need for inter-ethnic harmony, peaceful-co-existence and the need to promote a sustainable nationhood (Kundu, 2000);

(8) Stimulating students to read newspapers and books of non-communal nature, throwing light on the contributions of nationalists, will also help in creating national attitude;

(9) Acquainting students with the national projects and consequent progress will make them conscious of the greatness of their country;

(10) Talks may be given to the students on the living and food habits of people in different parts of the country to create better understanding;

(11) Festivals pertaining to different sections of the community may be celebrated with national outlook. They are the symbols of our cultural heritage and can be exploited to bring home to students the essentially basic unity of the Kenyan culture and their national background;

(12) The celebration of national days and secular festivals can also go a long way in promoting national consciousness. Once their imagination is aroused and they become emotionally aware of the significance of such occasions and demonstrations of our cultural solidarity, the festivals would be increasingly creative of a sense of community and national coherence;

(13) Documentaries and school broadcasts can promote national consciousness in students by highlighting the synthesizing trend in Kenyan culture;

(14) Exhibitions on the way of life people living in different parts can help to achieve emotional integration;

(15) Educational institutions can be helped in formulating “sisterhood programmes” among themselves. These programmes would envisage the visits of selected students of their institutions on reciprocal basis and provide opportunities for cultural activities, which will help in promoting cross-cultural understanding;

(16) The mass media should be used to sensitize the public on the potential dangers of inter-ethnic animosity that has been fermented in this country. Ethnic cleavages have been known to sow seeds of
discontent and enmity among the existing communities in a multi-party and multi-ethnic society. If such a situation goes beyond proportion, civil wars and internal clashes are inevitable.

References


Challenges Facing Managers in Managing Conflict in Schools in the South and South Central Regions of Botswana

Nnior Machomi Morake  
North West University (Mafikeng Campus), Mmabatho, South Africa

Ratau John Monobe  
University of Venda, Sibasa, South Africa

Stephonia Dingwe  
Private Bag F1, Francistown, Botswana

The purpose of this study was to examine the challenges facing managers in managing conflict in schools of South and South Central Regions of Botswana. In this study, the schedule of interview was used to collect empirical data. A random sample of 50 school managers and deputy school managers was selected for interviews. Major findings of the study revealed that school managers do not perceive conflict as an inevitable phenomenon that is real in any organization. They lack skills and strategies of handling conflict positively to produce good results. The study recommended that school managers should be trained on the importance and benefits of conflict. This training in conflict management will give them a skill that can enable them to turn conflict erupting in their schools into a positive force that can bring a positive change.

Keywords: conflict, conflict management, sources of conflict, conflict management strategies

Introduction and Background

This study focuses on the challenges facing educational managers in managing conflict in their schools. Conflict is an inevitable organizational reality that can bring negative or positive consequences within the organization. Conflict may lead to some disagreements in the organization, which might lead to good communication in an organization. This results in compromise or further appreciation of opposite views. According to Hoban (2004), the consequences of conflict can be described as positive. On the other hand, disagreement can result in polarization of viewpoints. Daresh (2002) argued that it can lead to the end of communication and personal animosity among members within the organization. In this case, the results of conflict bring about negative effects to the running of the organization.

Educational managers are charged with the responsibility of coming up with better ways of handling conflict in their schools. Namara (2002) emphasized that where possible they should come up with good tactics or strategies of managing conflict or guidelines of preventing it. Due to the size of the country and its sparse population, CJSS (Botswana community junior secondary schools) are scattered all over the country. The MOE (Ministry of Education) manages these schools and supplies and manages their resources. It is also responsible for the professional functions of teachers through its branches which are SDoE (Secondary Department of Education) and TSM (teaching service management). The SDoE is responsible for looking after 200 CJSS with the senior secondary school and it does this through its education officers based on different regions. Their role
is to supervise and ensure quality education system (MOE, 2000). The aim of TSM is to deploy teachers and it further deals with the welfare of teachers.

The duty of the Department of Curriculum Development and Evaluation Designs is to design, review and revise curriculum to meet the socio-economic needs of the country and that of individuals (Ministry of Education, 2000). MOE (2000) emphasized that schools should operate through the management of both senior management teams which comprise the school head, deputy school head and heads of departments, and school management teams which comprise of members of senior management and senior teachers of Grade one. Both management teams supervise, facilitate, make decision, act as instructional leaders, are responsible for staff and students welfare and ensure good relations within the schools. They are also responsible for managing day-to-day school operation (MOE, 2000).

Most of the managers in the education system rise to these positions without any prior management training. Some get these positions because of their long-service in the system, while others assume them because of their flowery curriculum vitae or having excelled in the interview (Bramson, 2004). This, therefore, suggests that SMT (school management team) should know the sources of conflict and strategies that can be used in reducing conflict in the workplace. For these reasons, sources and strategies of conflict management are discussed hereunder.

Sources of Conflict

It is clear that there is no organization without conflict. Hoban (2004) argued that in a school set-up incompatible goals occur because of reasons, such as a clash of personalities, personal value, lack or limited resources and others.

A Clash of Personalities

A clash of personalities occurs when an intense and highly energetic teacher has to work in the same environment with a slower and less intense teacher. In this case, the one who is a hard worker becomes irritated by the sloppiness and laziness of the colleague.

Personal Value

This becomes a cause of conflict due to diverging ideas or different perceptions of the same situation (Peterson, 2001). The difference in perception results in different people attaching different meaning to stimuli. Resolving value conflict does not mean that the disputants must change or agree on their values, but a mutual acknowledgement that each person views the situation differently is the first step.

Limited Resources

In most organization, resources are scarce and limited, which leads to individuals and groups to scramble or compete for their share (Hoban, 2004). This normally occurs when different parties have different priorities over scarce resource management and policy development. They involve a combination of economic, value and power sources. This is normally beyond the traditional management system.

Departmentalization and Specialization

Most organizations are divided into separate departments with specialized functions. Van Deventer and Kruger (2003) and Hoban (2004) argued that, because of familiarity with the manner in which they undertake their activities, departments tend to turn inwards and concentrate on the achievements of their own aims. This type of conflict may involve turf problems and overlapping responsibilities (Legotlo, Teu, & Matshidiso, 2003).
They went on to argue that this conflict occurs when one department attempts to assume more control or take credit for desirable activities, or give up its part and any responsibilities for undesirable activities.

**Status Struggle**

This occurs when one attempts to improve its status while another group views this as a threat to its place in the hierarchy (Legotlo et al., 2003). According to Van Deventer and Kruger (2003), a person’s perception of unjust treatment, such as the implementation of personnel policies and practices or in reward and punishment systems can lead to tension and conflict.

**Role Expectations**

Role expectations involve real differences in role or responsibilities among individuals who are interdependent in a work environment (Fisher, 2000). Daresh (2002) described it as the misalignment between the requirements of doing the job and the person selected to do the job. The conflict of role expectations occurs when different people including the person filling the post or the role disagree on how that role should be performed (Legotlo et al., 2003). The emotional extent is quite huge since human beings are involved and, in most cases, it is easy to personal the issue.

**Environmental Change**

Legotlo et al. (2003) and Van Deventer and Kruger (2003) argued that the changes in the organization’s external environment can cause a major area of conflict. These could be changes in the education system that can either be a situation of political changes and teacher-learner ratio at some schools.

**Communication Block**

Legotlo et al. (2003) and Gerardi (2004) indicated that communication block develops because not all groups have the same information. Each group, therefore, takes a stand on its view of the world and the information it has. According to Legotlo et al. (2003), communication problems frequently lead to conflict among people. If the school lacks proper communication, the situation can lead to antagonism and escalate and complicate conflict.

**Conflict Management Strategies**

According to Daresh (2002), Green et al. (2002) and Hanson (2003), conflict situations offer individuals an opportunity to choose a style they believe is more appropriate to responding to the prevailing conflict. The following are conflict management styles that can be adopted by educational managers in dealing with conflict in their schools.

**Cooperative Problem-Solving Strategy**

When using this style, people try to find a solution that will help them meet their interests and help everyone maintain good relationships. Dolphins are an example of this style. They whistle and click to communicate with each other to catch food cooperatively and summon help. But, they may choose other styles depending on the situation (Green, Glenford, & Plow, 2002; Hanson, 2003).

**Competing**

Choosing this style means that a person is putting his/her interest before anyone else’s interests. Some people who use this style try so hard to get what they want irrespective of whether or not they ruin the friendship. A lion is a symbol of this style. For example, when the lion’s family is hungry, the lion may use its strength and loud roar to get the food, because it is important for the family (Daresh, 2002; Green et al., 2002).
Compromising
People choose this style when it is important to satisfy some of their interests, but not all of them. They might say that let us split the difference for something better than nothing. A zebra is a symbol of this style. Zebras’s unique look seems to indicate that it does not care if it is a black or white horse, so it “splits the difference” and chooses black and white stripes, but it may choose other styles depending on the situation (Green et al., 2002; Hanson, 2003).

Avoiding
People choosing this style do not get in a conflict, they might say “You decide and leave me out of it”. A turtle is a symbol of this style, because it can avoid everything by pulling its legs and head into its shell to get away from everyone. It also chooses other styles, because it does not always have to stay in its shell (Green et al., 2002; Hanson, 2003).

Accommodating
People choosing this style put their interests last and let others have what they want. They believe that keeping a relationship is more important than anything else. A chameleon is a symbol of this style because it changes its color to match that of its environment. It also uses other styles depending on the situation (Daresh, 2002; Green et al., 2002).

Statement of the Problem

The school managers of CJSS around South and South Central Regions in Botswana are faced many challenges with an attempt to resolve conflict in their schools. A number of them, if not all, have not been trained in conflict management (Garegae-Garekwe, 1999). According to Garegae-Garekwe (1999), educational managers in schools have not developed sensitivity to potential conflicts both inside and outside the school. As a result, conflict that occurs in schools takes them by surprise and this leads to confusion and frustration.

The following are the research questions that guided and provided focus of the study:
(1) What are the causes of conflict in schools?
(2) Are the school managers adequately trained in conflict management?
(3) Which strategies are mostly adopted in managing conflict in the selected schools?

Aim and Objectives of the Study
The main aim of this study is to investigate challenges faced by educational managers in managing conflict in the CJSS around South and South Central Regions in Botswana. The following are the objectives of the study:
(1) To investigate the causes of conflict in schools;
(2) To find out whether school managers are adequately trained in conflict management;
(3) To investigate the strategies mostly adopted in managing conflict.

Significance of the Study
Underlying this study is the conviction that mishandling and mismanagement of conflict are the factors that hinder productivity and de-motivate staff, frustrate, anger and stress members. Based on this, MOE will ensure that educational managers receive adequate training in conflict management.

Research Design and Research Methodology
In this study, both literature and empirical investigations were conducted to gather more data on the
conflict management challenges faced by educational managers in CJSS around South and South Central Regions in Botswana.

**Literature Study**

A thorough study of primary and secondary sources was used to collect more information on the challenges concerning conflict management faced by educational managers in CJSS around South and South Central Regions in Botswana. The literature study also provides a theoretical background to an empirical study by means of interviews that helped in the recommendations and conclusions of this study.

**Empirical Investigation**

In this study, qualitative approach was used and interviews as research instrument to collect data from the respondents. According to MacMillan and Schumacher (2001) and Wiersma and Jurs (2005), the qualitative approach provides verbal descriptions to portray the richness and complexity of events that occur in natural settings from the participants’ perspectives. Once collected, the data are analyzed inductively to generate findings. The researcher chose it, because it allows for an inductive form of reasoning, and generalisation is the point of departure. It is in the form of themes and categories and allows for easier data analysis and there were no fixed rules that were used. In this study, deputy school managers and school managers were interviewed regarding the challenges they experienced in managing conflicts in their schools.

**Population and Sampling**

**Population**

MacMillan and Schumacher (2001) defined population as a group of elements or cases, whether individuals, objects or events, that conform to specific criteria and to which we intend to generalised the results of the research. In this study, population included CJSS in South and South Central regions of Botswana. These schools were chosen, because it was where conflict was being experienced mostly.

**Sampling**

According to MacMillan and Schumacher (2001), the smaller group or the subset is the sample. According to Monobe (2005), a sample is a group which is selected from the population and is thus less than the population, while remaining as representative as possible. In this study, sampling included 50 school managers and deputy school managers.

**Data Analysis and Interpretations**

An analysis of data in this section was done according to the research questions. The instrument was administered to 50 school heads and their deputies, but the researcher managed to interview 49. The analysis is as follows.

**Question 1: Do You Experience Conflict in Your Institution?**

The respondents agreed that they experience conflict in their institutions. This is in keeping with what Donais (2006) said that much conflict exists in every workplace. It is important to understand that conflict has the potential to either destruct or create a positive social change.

**Question 2: What Are the Sources of Conflict in Your Institution?**

The respondents indicated that, in most cases, the sources of conflict in their schools included lack of resources, for example, teachers fighting over the limited classrooms, laboratories as well as teaching and learning materials. They explained that clashes of personalities erupt more often when teachers are made to
share a house due to lack of accommodation. They also indicated that due to their lack of communication skills, there tended to be a communication breakdown between the teaching staff and the administration. These data tend to agree with what was said in the literature (Legotlo et al., 2003; Van Deventer & Kruger, 2003; Hoban, 2004; Gerardi, 2004).

**Question 3: Are You Able to Sense Conflict Before It Occurs?**

The respondents indicated that conflict was realized at the time when it surfaced and at a stage where it demanded for good and advanced strategies to manage it. This simply suggests that educational managers are not able to sense conflict before it occurs.

**Question 4: From Your Experience, Can You Say Conflict Is Good or Bad? Motivate Your Response.**

The respondents said conflict was neither good nor bad depending on how it was handled. They stated that if it was properly handled, it could improve the running and productivity of the institution. They further indicated that if mishandled, it could cause dissatisfaction among staff members and thus could disrupt the running of the school.

**Question 5: Have You Ever Gone for Any Management Training Before Assuming the Managerial Post?**

Some respondents indicated that they went for in-service training before assuming the managerial post. They complained that, they were not adequately trained in managing conflict and hence they were facing so many managerial problems.

**Major Research Findings**

In view of the presented data in paragraph 6, the major findings regarding the improvement of the management of conflict in schools are summarized hereunder. Conflict exists in any organization and there is no way it could be avoided, but it is vital for the manager to know how to handle it. Depending on how you handle conflict, it may bring positive or negative results (Dessler, 2001; Hoban, 2004).

**Question 1: What Are the Causes of Conflict in Schools?**

The school managers and deputy managers indicated the following as some of the causes of conflict in schools that:

1. Clashes of personalities cause conflict in schools;
2. Communication breakdown is a problem in schools;
3. Limited or lack of resources also causes conflict in schools.

**Question 2: Are the School Managers Adequately Trained in Conflict Management?**

When resolving conflict, the educational managers indicated that they could use collaboration, avoiding, competing and compromising strategies, depending on the conflict being handled (Daresh, 2002; Green et al., 2002). Educational managers assuming the responsibility without prior and adequate training cause a problem.

**Question 3: Which Strategies Are Mostly Adopted in Managing Conflict in the Selected Schools?**

The school managers and deputy managers indicated that the dominating strategies they mostly use are accommodating, avoidance, competing and compromising. People choose this style when it is important to satisfy some of their interests, but not all of them.

**Conclusions**

Little has been done as far as equipping managers with conflict resolution skills in JCSS of South and
South Central Regions in Botswana. This will help managers to no longer perceive conflict in the context of traditional point of view, where it is looked upon as a sign of non-performance and malfunctioning in the group, but rather in an integrationist’s view where conflict is perceived as a natural ingredient and a positive force that is necessary for a group to perform effectively (Robbins, 2003).

From the findings, most managers do not have the skills to distribute the limited resources fairly or expand their base where possible. They also lack the skill of communicating properly to their members of staff, this also leads. It is time managers are fully trained in conflict management skills so that they will be able to turn conflict that could, otherwise, be dysfunctional to be functional and that could bring positive development and change in schools. As revealed by the findings of literature review, conflict cannot be eradicated but should be used to unite the staff and pressurize them to search for new ideas. From literature review, most authors jointly agreed that conflict management is the key managerial skill that every manager should possess (Namara, 2002). A common consensus is that if conflict is not handled properly, it can cripple the day-to-day running of any institution and negatively impact on productivity, paralyze decision-making and prevent the achievement of organizational aims (Van Deventer & Kruger, 2003).

**Recommendations**

Training in conflict management will give them skills that can enable them to turn conflict erupting in their schools into a positive force that can bring positive change. This training will make them understand that conflict is inevitable, so it should not be perceived as a negative force that hampers productivity, but a force that leads to personal development and innovation. When people assume responsibility, they need training which covers the strategies of managing conflict in their institutions. They must know how and when to choose a particular strategy that will suit the situation.

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Students’ Evaluation of Teaching Quality*

Nina Vevere  
BIA (Baltic International Academy), Riga, Latvia

Vulf Kozlinskis  
Latvia University of Agriculture, Riga, Latvia

Students’ evaluations of teaching quality are one of the crucial components of the teaching quality evaluation (along with external evaluation, opinions of colleagues, etc.). According to our research and professional experience, the teaching quality has to be examined in correlation with personality traits of a lecturer. Students’ surveys (aiming at evaluating the teaching quality) have to consider the most valuable factors of the teaching quality and qualities of lecturers, which comprise knowledge transfer, knowledge evaluation, accessibility of a lecturer and his/her personality traits. In order to obtain quality results and compare them among various universities, a unified questionnaire should be applied when exploring the students’ evaluations of teaching quality.

Keywords: student evaluation of teaching, teaching quality evaluation methods, student survey

Research and Analysis of Results

Throughout the development process, universities of post-Soviet states, including Latvia, faced the necessity to improve its quality of education—due to the increasing competition with other (European) universities as well as the external (including state) requirements and control.

A lecturer’s input is the corner stone of quality assurance in higher education. One of the key elements of evaluating the quality of teaching and lecturers is students’ evaluations of teaching quality.

At the same time, many authors, e.g., Berk (2008-2009), Cashin (1989) and Way (1993), fairly considered that results of student surveys are more applicable as a feedback tool. For instance, Berk (2008-2009), while admitting that the pivotal role rests with the students’ evaluations, pointed out that it may be biased or even prejudiced due to its subjective nature. Thus, it is the essential, but not sufficient source of information. Way (1993, p. 220) stated that the evaluation of teaching quality and a teacher by students may be taken into consideration only when examining the teaching quality and providing feedback. Such authors as Cashin (1989, p. 3) contemplated that the evaluation of teaching quality and teachers by students should take into account that students may be able to provide an objective evaluation of only four of the following components: knowledge transfer, knowledge evaluation, availability of a lecturer, administrative requirements, i.e., teachers’ presence during lectures, sufficient supply of library with relevant literature, etc..

Surveying is a widely used method to evaluate the teaching quality (a case of external control, when the evaluation is undertaken by experts during discussions with students, is an exception). In this respect, a number of essential questions arise on contents of a questionnaire, surveying techniques and analysis of results. Scriven

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Nina Vevere, Ph.D. candidate, lecturer at the BIA (Baltic International Academy), inspector of Personnel Department at BIA.

Vulf Kozlinskis, Ph.D., professor, vice-rector of research at the Riga International School of Business Administration, Latvia University of Agriculture.
(1995, p. 3) stated that data provided by students are reliable, if survey questions contain “verifiable criteria” instead of “dubious indicators”. Too wide questions lead to erroneous conclusions. One of the most common errors is the use of questions, which concern comparisons of teachers and their methods or “finding out whether their course is the best among those taken by the students”. The American professor Berk (2008-2009) distinguished 14 potential sources for teaching quality evaluation (i.e., evaluation by students, colleagues, external experts, self-evaluation, video, student interviews, evaluation by graduates, employers, managers, as well as grants, academic awards, transcripts and a teacher’s portfolio).

The analysis of more than 40 various questionnaires employed for surveying in Latvia and Russia has indicated the lack of clear surveying principles (which do differ considerably in terms of volume and contents). Even within one country (for example, Latvia), the student surveys are not directly compatible since the results derive from questionnaires differing by contents and scope. For instance, the number of questions ranges from 13 to 40. The similar situation is observed in Russia. Having examined the surveys conducted in several Russian and Latvian universities, the authors found out that, in spite of the variety of questionnaires in terms of volumes and contents, the questions are not systematic. Some universities developed their own questionnaires and others used commonly known and approved methods. One of the well-known examples is the “education quality evaluation map” by students. The map elaborated by Saint-Petersburg State University, Herzen University and Pomor State University contains 13 questions (quality indices) (Bordovskaya & Titova, 2003). The aforementioned method is used by Pomor State University (Vorozhcova et al., p. 8). The Institute of the Commonwealth of Independent States (2007) has worked out its own methodology and criteria of education quality evaluation. The method involves conducting surveys among the following target groups: managers, lecturers and students.

Along with defining the evaluation principles, it is necessary to define the notion of teaching. A renowned expert in higher education, Fink (2002, p. 47) stated that teaching is “the assistance to someone in studying something”, while a “successful (good) teaching” is “the effective support of someone, who studies something significant”. These two elements are the vital components of co-operation process between teachers and students. In addition, it is required to consider personality traits of a lecturer. Arreola, Theall, and Aleamoni, (2003, p. 4) stated that teaching involves four types of expression: (1) mastery, which means achieving of the highest level in a given subject area; (2) discovery, which includes all forms of research; (3) expansion which are announcement of research results concerning new products, services or actions valuable for the society at large; and (4) realization-implementation of research results, e.g., new products, services or actions valuable for the society at large. Cashin (2003, p. 531), following the viewpoint of Arreola et al. (2003), pointed out that teaching involves seven components: mastery of a subject, course materials, detailed elaboration of a course, knowledge transfer, knowledge evaluation, accessibility of a lecturer and administrative requirements.

The psychologist and lecturer of Oxford University, Herbert T. Marsh, invented a special SEEQ (students’ evaluation of education quality) tool, which allows measuring the effectiveness of teaching at universities as per the following criteria: learning, enthusiasm, clarity, co-operation with a group, individual approach, presentation scope and interpretation, evaluation, homework and course complexity (Marsh & Roche, 1997, p. 1188). Ramsden (1994), the head of the UK Higher Education Academy, pointed out that the main aim of analyzing the teaching quality at universities is to encourage lecturers to look at the teaching process from the viewpoint of students, being aware of their thoughts and actions. Ramsden administered a questionnaire, containing 24 questions within the following six groups: qualitative teaching, clear goals and standards,
appropriate evaluation, appropriate scheduling, essential skills and overall contentment. In 2002, the Australian Government financed Ramsden’s research. Then, five additional groups were added to the questionnaire: personal traits of graduates, intellectual motivation, student community, teaching resources and student support (Harris & James, 2006, p. 5). Nowadays, Flinders University, Royal Melbourne Institute of Technology, The University of North Carolina at Chapel Hill, The University of New South Wales and other educational institutions use the aforementioned questionnaire to evaluate the quality of teaching.

Oxford University has also elaborated its own questionnaire as a part of the internal evaluation system of the teaching personnel, having added six additional questions to Ramsden’s original 24 questions.

In order to enhance the quality of teaching, Stanford University (1997) recommended its lecturers to study four skill-demanding topics. The first two can be subject to change, while the latter are resistant to changes. These topics are: (1) clear presentation and compliance with teaching goals; (2) oral skills, or teaching tempo; (3) development of students’ conceptual understandings and/or critical thinking; and (4) homework planning to enhance the learning process.

Vattano (1987), professor of Colorado State University, compiled the teaching manual which consists of materials designed to improve the quality of teaching in line with ten criteria of teaching quality.

In our literature review, we attempted to sum up the teaching quality evaluation criteria used by the abovementioned authors. Agreeing opinions are marked by sign “+” (see Table 1).

Table 1

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<th>The Teaching Quality Evaluation Criteria (As Suggested by the Authors)¹</th>
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<td>Criteria/author</td>
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<td>Group No. 1: Knowledge transfer</td>
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<tr>
<td>Subject knowledge, professionalism</td>
</tr>
<tr>
<td>Organization and preparation, elaboration of teaching materials</td>
</tr>
<tr>
<td>Knowledge transfer</td>
</tr>
<tr>
<td>Clarity and teaching quality</td>
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<tr>
<td>Co-operation with students, group work</td>
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<tr>
<td>Home work</td>
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<tr>
<td>Course complexity, workload</td>
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<tr>
<td>Practical skills</td>
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<tr>
<td>Group No. 2: Knowledge evaluation</td>
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<tr>
<td>Knowledge evaluation</td>
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<tr>
<td>Administrative requirements</td>
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<tr>
<td>High standards and transparency</td>
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<tr>
<td>Group No. 3: Personal traits</td>
</tr>
<tr>
<td>Enthusiasm</td>
</tr>
<tr>
<td>Perception of students’ needs</td>
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<tr>
<td>Openness</td>
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<tr>
<td>Sense of humor</td>
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<tr>
<td>Moral values</td>
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<tr>
<td>Modesty</td>
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<tr>
<td>Objectivity</td>
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<tr>
<td>Relationship focus</td>
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</tbody>
</table>

In Table 1, we also divided the teaching quality evaluation criteria into three groups. According to W.

¹ Table 1 lists the teaching quality evaluation criteria, which can be included into the unified student survey.
Cashin, “accessibility of a lecturer” can be the fourth group.

The consolidated table indicates the high level of disagreement on prioritizing the teaching quality evaluation criteria among authors. Thus, five out of six authors did not take into account the aspects of group work, as well as the attitudes of students towards home tasks. Simultaneously, five out of six authors agreed on the importance of preparation (elaboration) of teaching materials and knowledge evaluation.

Table 1 also shows that the aforementioned authors concentrated their attention on some aspects of the teaching process, disregarding other essential components.

The analysis of international experience in conducting the teaching quality evaluation surveys allowed the authors to improve contents of the student questionnaire. The experience of both the world’s most prestigious universities and the ones aiming to reach the international level was involved.

Table 2

<table>
<thead>
<tr>
<th>Questionnaire section</th>
<th>Criteria</th>
<th>Positive evaluation (percentage)</th>
<th>Neutral evaluation (percentage)</th>
<th>Negative evaluation (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal traits</td>
<td>Speech culture</td>
<td>88.55</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Respect for an audience</td>
<td>88.4</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Appropriate outer appearance</td>
<td>87.87</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Responsiveness</td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Punctuality</td>
<td>84.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good manners</td>
<td>84.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The ability to control and discipline the audience</td>
<td>84.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge transfer by lecturers</td>
<td>Supplied with excessive workload</td>
<td>25.45</td>
<td>28.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Opposed different theories</td>
<td>30.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Asked students about their goals</td>
<td>28.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduced topics appropriately</td>
<td>87.71</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Asked students about their learning interests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Encouraged students to focus on their interests and goals</td>
<td>28.03</td>
<td>14.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Provided with appropriate practical examples</td>
<td>84.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Explored learning issues fully</td>
<td>84.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ensured the required supply of literature and handout materials</td>
<td></td>
<td></td>
<td>11.41</td>
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<tr>
<td></td>
<td>Offered different viewpoints to the learning issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inspired students for further reading</td>
<td>25.52</td>
<td>16.89</td>
<td></td>
</tr>
<tr>
<td>Knowledge evaluation</td>
<td>Offered students to evaluate themselves</td>
<td>31.46</td>
<td>23.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Asked students how they intend to achieve the goals and tasks set</td>
<td>29.67</td>
<td>19.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offered students to share their ideas and knowledge</td>
<td></td>
<td></td>
<td>13.08</td>
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<tr>
<td></td>
<td>Explained students why they were right or wrong</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Opened new learning opportunities</td>
<td>25.41</td>
<td></td>
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</tbody>
</table>

The authors elaborated the student questionnaire that allows evaluating teachers and the teaching quality

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2 Conducted in seven Latvian Universities (2009-2010).
by certain criteria. The questionnaire contained dichotomous questions divided into four groups: knowledge transfer, knowledge evaluation, accessibility of a teacher and his/her personal traits. The questionnaire was approbated and then used in seven Latvian universities. The research results are shown in Table 2.

The results show that Latvian students evaluate the teaching quality positively. This fact contradicts with the current quality level of the higher education in Latvia and suggests that students evaluate the teaching quality subjectively due to limited opportunities.

While analyzing the survey results, the authors focused their attentions on the negative evaluation of teaching (in order to explore new opportunities for improving the teaching quality).

Over 28% of students think that it is possible to fully meet course requirements set by a lecturer.

As anticipated, most of negative evaluations concern the “knowledge evaluation” section. For instance, over 11% of students are discontented with explanations that were given to justify evaluation of their knowledge. Over 23% of students assess their self-evaluation options negatively (in terms of the overall knowledge evaluation system).

The survey results clearly designate that there are plenty of education quality improvement opportunities.

Personal traits of a lecturer have an unexpectedly high influence on students’ motivations and the learning processes. Therefore, in order to explore the students’ potential and assist them in becoming independent and mature personalities, the lecturers have to put more emphasis on interaction with the students and progress personally.

Summing up personal qualities listed in the questionnaire, the surveyed students thought that lecturers should be good-tempered, understanding, punctual, tactful, intelligent, considerate, patient, fair, attentive, accurate, sociable, objective, creative, positive, sympathetic, talented, responsible, hard-working, forgiving, supportive and able to give an appropriate advice.

At the same time, the research showed that the students found unacceptable traits of a lecturer, such as rudeness, quick temper, nervousness, being reserved, susceptibility and indifference.

As a result of the conducted survey, the authors also identified a number of factors that can impact on survey results considerably. They are:

1. The number of students in a target group;
2. The amount of required information obtained during a survey;
3. The number of years students have studied (e.g., first year or graduate students);
4. The education level (Bachelor, Master or Ph.D. programme students);
5. The survey goals (to obtain certain information about particular or general issues);
6. The evaluation methodology, e.g., precise (in-class) evaluation or detailed (take-home) commentary;
7. Timing of a questionnaire (at the beginning of a course—to clarify the background information or at the end—to draw conclusions);
8. Clarity of the research subject;
9. Single-use or multiple-use questionnaire;
10. Means of information processing;
11. Announcement of the survey results to all interested parties.

The unified survey helps to raise teachers’ motivations in improving education level of students as well as their own professional level, at the same time, making students more aware and critical to the study process, teaching methods and a university as such. Elimination of indifference to the study process and the improved
feedback are the most favorable survey results. The academic staff must find out what exactly needs to be changed, what cannot be changed, what kind of changes have to be made to allocation of resources, teaching/learning materials, academic plan, etc., and conclude whether teachers are ready to change and improve themselves.

The analysis and the authors’ experience gave a clear indication of the significant problem—in the post-Soviet states, the acquired results are not used efficiently even given the well-structured and effective system of the teaching quality evaluation. “The definition of insanity is doing the same thing over and over and expecting it to come out different”, said by Benjamin Franklin.

Conclusions and Recommendations for Further Researches

One of the most crucial factors in the system of teaching quality evaluation is the evaluation of teaching by students. Simultaneously, due to subjective nature of the students’ evaluation, it can be regarded as an instrument enhancing feedback among universities, students and lecturers, whereas improvement of the teaching quality is a prerequisite. In order to determine the student’s evaluations of teaching quality, it is more efficient to use a unified questionnaire and compare results across several universities. The key groups of criteria that should be included in a questionnaire are: knowledge transfer, knowledge evaluation, accessibility of a lecturer and his/her personal traits. The unified questionnaire can be modified for a particular university by adding a supplementary section based on students’ answers to open questions. Relationships between students and teachers are the unexpectedly crucial component of the teaching quality evaluation. In most cases, the relationships are the main driver that motivates students strongly for studies, exploration of new materials and own researches. Despite of the fact that evaluation of one university lecturer concerns interests of all other lecturers, not everyone in teaching personnel gives considerable attention to this process and strives for positive results, whilst evaluation of the teaching personnel is capital-intensive and rather complex. The role of a student in this kind of evaluation is really significant provided that the applied methodology is efficient. Further research on this topic should consequently reveal differences in the evaluation of teaching by students with different educational backgrounds (for instance, at the Bachelor and Master levels).

References


STUDENTS’ EVALUATION OF TEACHING QUALITY

Conducting Assemblies in Botswana Public Schools

Dinama Baamphatlha
University of Botswana, Gaborone, Botswana

In this paper, the author explored the teachers’ experiences and their views regarding how assemblies are conducted in Botswana public schools. The author indicates that assemblies are a common feature in Botswana primary and secondary schools. The author adopted the Christian Privilege as the conceptual framework as espoused by Blumenfeld (2006) that the Christian religion is given an undue favor in various social institutions including schools, yet Botswana is a liberal democracy according to its constitution. The study drew on interviews from 18 in-service RE (religious education) teachers at the UB (University of Botswana)—Nine of the participants were primary school teachers, while the other nine were secondary school teachers. The sampled teachers were unhappy with worship in assemblies and were not aware of the conscience clause in the Botswana Constitution and Education Act which allows freedom to worship or not. The author concluded that collective worship is contestable since it emphasizes conformity, conversion and the promotion of the Christian religion and its values, hence making teachers uncomfortable especially those who are not Christians and those who do not practice religion. The author suggested that worship should be taken out of the school assembly and replaced by religiously neutral activities.

Keywords: school assembly, public school, liberal democracy, Botswana constitution, Christian privilege, domination, religious education teachers, worship

Introduction

Most of the former colonies of the West especially in Africa have inherited educational legacies of their former hegemonic powers. One such practice is worship in schools at assemblies, which Botswana adopted from the British education system. In Botswana public primary and secondary schools, teachers enforce worship, whereby students are required to start an assembly with the singing of Christian songs, reading of the Bible and ending with a Christian prayer. However, the practice can be located within the broader cultural practices since it tends to be a convention in terms of family, community and other public meetings. At times, students are asked to memorize some verses from the Bible in order to recite them during assembly. Worship is school-based religious activity, in which the whole school community or some classes gather at assembly with an aim of exposing the participants to Christian worship. A school assembly is that when the school community or a part of it meets together to share aspects of life that they deem worth to them. It is aimed at creating and sustaining a sense of community, so that the students and the school personnel live harmoniously in terms of sharing certain values (Hawkes, 2000). Worship is one practice that is sanctioned and is about giving praise to the object perceived to be worthy by a particular religion. Though collective worship is a common practice, there is little consensus regarding its aims. The practice is not without controversy since it is a contentious

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Dinama Baamphatlha, Ph.D., lecturer, Department of Languages and Social Sciences Education, University of Botswana.
activity and contestable especially in a diverse and plural society (Cheetham, 2001; Copley, 1994; C. Erricker & J. Erricker, 2000; Hull, 1998; Lester, 2007; Louden, 2004; MacMullen, 2007; Watson, 1993; Webster, 2000; Yousif, 2000). Constitutionally, Botswana is a liberal democracy, hence worship brings a lot of disagreement in terms of the assumptions it makes and the type of knowledge it seeks to enhance, the type of behavior it proposes to promote and the wide range of ideals it tries to approve. Worship in the school community at assembly has been viewed as being able to bring harmony, stability and the maintenance of the social order in a group (Bastide, 1992; Klein & Chen, 2003; Webster, 2000). The aim of worship is to “turn the school into a worshipping community and the assembly into a place of worship” (Hull, 1998, p. 124). In public schools and also in liberal democracies, worship is viewed as out of place, irrelevant and inappropriate because a school is a collection of individuals representing diverse beliefs, cultures and backgrounds (Van Brummelen, Koole, & Franklin, 2004). For teachers and students who are Christians, it could be a source of joy and spiritual upliftment while that might not be the case with non-Christians. In the Botswana context and upon employment, a teacher is assumed to be a Christian and being enrolled in a school becomes an act of religious commitment on the part of the student. Consequently, this gives rise to sanctioning of Christian privileges in Botswana public schools. However, the Constitution of Botswana (Botswana Government, 1966) and the Education Act (Botswana Government, 1971) do not prohibit worship in public schools.

**Conceptual Framework**

Christian privilege is a system of benefits that confers dominance on Christians while subordinating members of other faith communities as well as non-believers (Blumenfeld, 2006; Louden, 2004). It is the institutionalization of Christian norms or standards that establish and perpetuate the notion that all people are or should be Christians. The privileging of Christians and Christianity excludes the needs, concerns, religious, cultural practices and life experiences of people who are not Christians. However, in a liberal democracy, there is the accommodation of incompatible values (Moulin, 2009) as well as an emphasis on autonomy in terms of choosing one’s beliefs (Thiessen, 1995).

The public school system is among the most important social institutions where this privilege is evident. The state in Botswana seems to have “officially” (emphasis mine) legitimized Christian beliefs as official practices of the state, for example, Christian prayers and hymns. In this way, schools become historical embodiments of ideological forms in terms of privileging certain groups and asymmetrical relations of power that sustain such privilege (Giroux, 1995). Schools then portray reality in unitary ways that fail to acknowledge the heterogeneous multi-layered and often contradictory nature of society (Giroux, 1995). Viewed in this way, schools then become ideological and political terrains out of which the dominant culture, in part, produces its hegemonic “certainties” and popular assurances or received orthodoxies (Giroux, 1995, p. 38). Christian values then become the dominant culture that schools reproduce, promote and protect. That is the reason why Giroux (1995, p. 38) said that as a result, schools become “implicated in the production of subjectivities”. In this way, schooling can become hurtful to particular students and teachers whose identities are ignored and excluded from the mainstream culture (Kincheloe, 2004). Such a practice privileges students from a dominate culture’s background, while at the same time undermining the interests of those who fall outside it (Kincheloe, 2004). In public school setting, dominant power and control operates in numerous and often hidden ways (Kincheloe, 2004), hence it is difficult to uncover this privilege of Christian hegemony. Furthermore, students who are not Christians are not allowed to “make meanings and create their own cultural histories” (Giroux, 1995, p. 38).
CONDUCTING ASSEMBLIES IN BOTSWANA PUBLIC SCHOOLS

Non-Christians in a school setting become a subordinated, restricted and disempowered group. In this way, the dominant privileged group imposes its own values on the subordinate group (Blumenfeld, 2006; Du Preez, 2004; Jankie, 2001; Miller, 1988). For example, non-Christian perspectives will be viewed as inferior, false or dangerous and their adherents perceived as non-believers who are immoral and misguided. The superordinate group imposes and defines its prescribed cultural norms, values and perspectives on members of the subordinate group (Bryan, 2011; Miller, 1988). The prescription and definition is in terms of what are good and evil, health and sickness, normality and deviancy, and how one should live one’s life. The normative assumption is that non-Christians lack many things hence they live inadequate and abnormal lives. Due to this assumption, there are advantages that accrue to Christianity and stereotypes that are formed which are perpetuated by the dominant group and will then permeate society to the extent that they are not noticed or contested. Since the stereotypes are covert and hardly noticed, they are hardly, if ever scrutinized, analyzed or confronted by society yet they do exist. In this way, the dominant group successfully disseminates dominant social constructions as being commonsense, normative and universal (Gramsci, 1971; Young, 1990). Consequently, the experiences and culture of the dominant group becomes internalised and universalised by both groups.

Worth noting is that the subordinate group internalizes these stereotypes and the interiorized images of itself. Consequently, this group becomes invisible because its perspectives and cultural expressions become invalid and unacceptable and its members are marked as different. For example in Christianity:

Students of other faiths and non-believers, … see few of their perspective and few if any, … people who believe as they believe or people who adhere to the cultural expression that they adhere to introduced and discussed in their classroom lessons. (Blumenfeld, 2006, p. 198)

Since schools through teachers and the curriculum have authority regarding students’ knowledge (Jankie, 2001), they describe and name the world using the language and cultural expressions of the dominant religion. For instance, in school assemblies, there is a great loss of identity and self-worth of non-Christians, since they are made not to belong to the “normal” and real world but are forced to see themselves through the eyes of the Christians. An assumption can be made that the state is “officiating” Christian practices and is aiming at socializing young people into a particular culture with an attempt to create a homogenous and ethnically homogenous nation state with a common culture in terms of language and religion.

Furthermore, this subordination may not be enacted primarily through official laws and policies but in informal often unnoticed and unreflective conventional practices of everyday interaction (Young, 1990). The dominant group unconsciously uses dominant social values to justify and rationalize social oppression. However, the dominant group often lacks awareness or understanding of the ways in which it is privileged on the basis of its social identity. For example, what a subordinate group may view as oppression, the dominant group views it as simply living their lives, because they do not understand themselves as agents of oppression. In this way, “Christian religious traditions are often observed… with little sensitivity to the religious beliefs of other groups” (Anderson & Taylor, 2008, p. 250). In school assemblies, Christianity is viewed as being a part of the natural order and a representation of what is normal in terms of religious holy days and organized prayers. Schools are turned into permanent worship places while Christian prayers are viewed as appropriate, preferable and acceptable. Non-adherents of Christianity cannot avoid worship, as it is forced on to them to incorporate it in their lives as members of a school community. Furthermore, the pervasive nature of Christian privilege is the
latitude of Christians to openly convert in schools. The study aimed at understanding the teachers’ lived experiences as they are a part of the school community where worship is practiced and forms an integral part of school assembly.

**Research Question That Guided the Study**

The research questions are as follows:

1. What are the teachers’ views on school worship during assembly?
2. To what extent are teachers aware of the withdrawal clause of the Botswana Constitution and the Education Act?

**Methodology**

The author adopted a qualitative interpretive approach using purposive sampling in order to explore the practice of worship in school assemblies as experienced and lived by teachers. The practice is contestable and some have misgivings about it. The study draws on interviews from 18 in-service RE (religious education) teachers at UB (University of Botswana). Nine of the participants were primary school teachers, while the other nine were secondary school teachers. The author interviewed the teachers regarding their experiences about compulsory worship in school by asking them to say how it is done in the various schools where they teach. The author also solicited their views about their awareness of the withdrawal clause in the Constitution of Botswana (Botswana Government, 1966) and the Education Act (Botswana Government, 1971). The author used interviews in order to understand what meanings they associate with worship in schools since they are a source of rich data in terms of directly experiencing the phenomenon. In a qualitative research paradigm, one way of learning about people’s experiences is to ask them about their experiences by listening carefully to their stories (Auerbach & Silverstein, 2003) and this is the reason why the author used interviews.

In the group of participants, there were three sub-groups and these were Christians, religious but non-Christians and those who said that they were non-religious. However, in carrying out this study, the author was being reflexive in terms of being aware of his values that he brought with himself into the study. The author have been a student in Botswana public schools where worship is practiced, as well as being a teacher of RE of which the subject of worship is always discussed as a dimension in the study of religion. As entering into the study, the author was also a source of knowledge about the phenomenon of worship in schools.

When collecting data, the author audio-taped the interviews which were transcribed and then coded according to the patterns and contradictions that emerged. From the patterns and contradictions that emerged, the author developed theoretical constructs (Auerbach & Silverstein, 2003) or themes that elucidated the experiences and views of the teachers.

**Discussion and Analysis of the Findings**

**Teachers’ Experiences on Worship in Public Schools**

In Botswana, worship during assemblies is widely practiced from a Christian perspective. However, individual teachers have a legal right to withdraw and may not be discriminated against in any way for exercising such a right. The practice of this right tends to be unclear to teachers. Both the Constitution of Botswana (Botswana Government, 1966) and the Education Act (Botswana Government, 1971) protect the individual’s right of conscience. Section 11(3) of the Botswana Constitution states that:
Except with his own consent (if he is a minor, the consent of his guardian) no person attending any place of education shall be required to receive religious instruction or take part in or attend any religious ceremony or observance if that instruction, ceremony or observance relates to a religion other than his own.

Similarly, the Education Act Section 22 (1 and 2) (Botswana Government, 1971) states that:

Religious instruction may be given in any school. If the parent of any pupil in attendance at any school request the principal of that school in writing that the pupil be wholly or partly excused from attendance at religious worship and religious instruction in the school, then, until the request is withdrawn, the pupil shall be excused from such attendance accordingly.

Teachers described a similar pattern of conducting assembly in their respective schools whereby worship forms an integral part of the activity even though it was also expressed in various ways by different teachers. Teachers indicated that worship is only Christian inclined, even though the school community is diverse. Teachers described their experiences regarding how assembly is conducted in Botswana schools. The following examples illustrate the place of Christian worship at assemblies.

Kelly: Assemblies are conducted daily or on certain days before lessons whereby Christian hymns are sung and prayers are said by both pupils and teachers. In some instances a pastor or any Christian is invited to conduct the worship, and later announcements and other items follows. The arrangement to invite a pastor is made by school administrators.

Kim said that: “In primary and secondary schools daily worship is conducted either each morning or any other day reserved for such an activity”. Gertrude also observed that normally, assemblies begin with a Christian hymn followed by a Christian prayer, such as “The Lord’s prayer” or “The Lord is my shepherd”. Mosadi and Becky further emphasized the point of worship as a common practice.

Mosadi: Worship is widely practiced in Botswana primary and secondary schools. We start with a Christian hymn and everybody joins in the singing, followed by a reading from a Bible and a prayer. The worship takes place in the morning to begin the day and it is compulsory for every member of the school community to worship.

Becky: In Botswana primary and secondary schools, worship takes place during assembly in the morning. During worship, Christian songs are sung, followed by a Bible reading and lastly a Christian prayer. When students refuse to sing or pray, they are seen as disrespectful and are punished. Teachers are under pressure to Christianize worship to a point that when they talk about values, such as cooperation and patience, they read some stories from the Bible to justify what they are saying.

There was an indication that missionary work has an influence on the way assemblies are conducted in Botswana as expressed by Kay who said that: “Worship was actually pioneered by the Christian missionaries”. Solly further emphasized the point by saying: “Christian missionary influence has led some to view schools as a continuation of the practices of the Christian faith community”.

Lonnie said: Historically Christian missionaries were the pioneers of formal education in this country and their missionary work had also an impact on our culture in Botswana because many were converted to Christianity. As a result Christianity formed an integral part of our culture whereby children now understand Christian practices without being converted to it.

Not All Members of the School Community Are Practicing Christians

Teachers were uncomfortable with the practice of worship at assembly, because they argued that the school community comprises people who belong to diverse religions and even those who do not subscribe to any religion. Jakes indicated that the school community comprises people who do not all belong to Christianity
even though all may have an idea of what Christianity is. Kim and Kelly had a similar view.

Kim: I do not support worship in school because it has an element of indoctrination hence makes me uncomfortable. It does have room for the diverse cultures let alone diverse religions. It is always Christian-based it is not inclusive and has no place in a modern democracy. It is usually assumed that everybody in the school is a Christian and the assembly is regarded as a sacred place. The practice fails to accommodate people from diverse backgrounds that make up the school community.

Kelly: I am not against Christianity, Buddhism or any other religion, but I do not support worship in schools, because it enslaves pupils instead of giving them freedom of choice. It is also a sign of insensitivity to followers of other religions that are different from Christianity who are viewed as unimportant in this context.

During assembly, teachers would naturally show respect to the practice by suppressing their beliefs and pretending, as if there were no religious differences. Matty was of the view that schools assume that there are no differences in terms of Christian religious beliefs or even lack of them. She said that: “When pupils come to school, they already have their religions or beliefs and they should not be forced to abandon them to follow Christianity. Pupils are conditioned to accept Christianity and its teachings”. The point was further corroborated by Gertrude and Mosweu.

Gertrude: Worship is of a Christian character and ignores the diverse composition of the school community which comprises members from different backgrounds like beliefs and faiths. This practice makes some people conform to Christianity. In some primary schools, children are punished by being beaten for failing to sing, lead prayers or recite some verses from the Bible properly. Other schools even go further to reward pupils who lead in Christian songs sung during worship at assembly which is totally unacceptable. Rewarding students who engage in a religious ritual gives the impression that Christianity is unique and better than other religions. Similarly, punishing students for failing to practice a foreign religion is offensive to the conscience of the student. Personal and private beliefs need to be separated from the public values.

Mosweu: Although Christianity is dominant in this country, not all are Christians because some school-going children practice the religions of their parents who are not Christianity. The rights of the few are infringed upon because they are denied the opportunity to practice their religion whilst others are allowed and supported by the school.

Some teachers were of the view that worship should not be practiced in schools, because it is morally inappropriate. For example, Sandra said that, “This act of worship is not appropriate and therefore does not have a place in our schools”. Solly was against worship because he said, “It is a private act that should be confined to the home or church and the school should be left for syllabus instruction”. The issue was taken further by Rita.

Rita: I think worship should not be practiced in schools. If schools see worship as an essential part of pupils or students’ moral development then it should be designed and conducted in manner which does not favor one religion over others.

Just like other teachers, Mosweu observed that, “Worship during assembly is aimed at converting and indoctrinating the students”.

Mosweu: Worship during assembly aims at converting students to Christianity by painting a positive image of God and Jesus and this makes children adopt Christianity and turn against their religion. This is not right because at this tender age, children are easily influenced because for some worship at school might be their first religious experience.

Even though teachers were in support of a school assembly, they were of the view that worship is
inappropriate in a multi-cultural and multi-religious nation such as Botswana. Teachers indicated that worship of a Christian nature is an unfair practice to some teachers and students who are not Christians since it offends their conscience. Teachers viewed worship as being discriminatory against those who are not Christians and also making them conform to a religion which is not theirs, hence creating unclear identities especially on children.

Rita: Compulsory worship in schools is not right because children who are not Christians are being discriminated against at an early age. I am against the practice because it can mislead children to think that Christianity is the right religion. Children from a Christian background enjoy it because it is what they practice in their own religion because if a pastor preaches to the school community some will be shouting “hallelujah amen”, clapping hands and expressing their shared experiences with the preacher.

Sandra said that Christian worship in school assemblies is unfair, because it is not inclusive of other religions. She argued that it discriminates because it exposes students to Christianity only. Similarly, Becky was of the view that since Christians are a majority in Botswana, they use their numerical strength to oppress the minority non-Christians. Rita complained that forcing children to participate in worship encourages them to live a life of pretence. Similarly, Solly was of the view that compulsory worship could have a negative impact on children who may end up hating religion.

Rita: Children then pretend to be holding the same beliefs with those who see meaning in Christian worship. This practice can encourage such children to be dishonest in life because they may think that in life you can survive through pretence. Moreover, they may have a low regard for religion by perceiving it as a fallacy.

Becky: The assumption and belief is that most people in Botswana are Christians so worship should be Christian. This clearly indicates oppression of the minority. Non-Christian students and teachers are expected to betray their beliefs and express what they do not believe in by singing songs and prayers that are Christian. This demeans the integrity of these individuals and also violates their freedom of worship and conscience. Forcing non-Christian children to sing and recite Christian prayers is not proper and is legally unacceptable according to the Constitution of Botswana.

Alternatives to Collective Worship

Teachers suggested alternatives to worship, conducting an assembly in a public school that was not necessarily religious in nature. Gertrude and Kelly suggest that assemblies can still be used to address issues that may not necessarily be of a religious nature. They said that the assembly could be used to teach about emerging issues, such as environmental education, HIV (human immuno-deficiency virus) and AIDS (acquired immuno-deficiency syndrome), truancy, vandalism and theft.

Another alternative to worship was to expose students to various forms of worship in different religions. For example, Becky was of the view that religion can still have a place in an assembly if various religions formed a part of worship.

Becky: During assembly different activities from different religions can be done instead of drawing all activities from one religion-for instance a hymn can be from Christianity and a Muslim student could be asked to pray. Students from different religions could take turns in preparing for and conducting assemblies. Adherents of different religions could also be invited to present at assembly. Including various religions during assembly does not only promote diversity but also make assemblies interesting and broad as opposed to the mono-cultural worship which is narrow and monotonous. Another alternative would be to give students time to reflect and have an inner dialogue with themselves by devoting some minutes of silence.

However, some found that such a move could be a source of conflict where each religion would need a
space in the school calendar to express its worship forms. Others were of the view that it would be superficial if such an arrangement were to be made. There were those who were of the view that worship should completely be removed from assembly in public schools. Becky’s point was corroborated by Matty who said that, “The schedules should be drawn in such a way that it caters for students of various religions in school and not Christians only”. Maggie emphasized the point further by indicating that the different religions that exist in a particular society should be reflected in school worship to show the inclusive nature of the assembly. Inclusion of different religions looks attractive, but that might not be a plausible alternative bearing in mind that various religions compete for space, which is not the aim of education to see religions competing. After all, Christianity might have leverage, since outside the school it is viewed as “the religion” (emphasis mine).

**Religious Education Teachers Should Conduct Worship**

The RE teachers were unhappy that their colleagues in schools viewed them as the appropriate people to conduct assembly and worship.

Sandra: Since worship is of a Christian nature, it makes work and life difficult for RE teachers who teach a multi-faith curriculum. We find ourselves talking more about Christianity at assembly and nothing about other religions and this makes students to question our credibility as RE teachers. Other teachers in the school expect us to conduct assemblies because during assembly worship which is a religious activity takes place. This even leads to some RE teachers not seeing the need to teach some aspects of the curriculum which they believe are covered during worship at assembly.

Just like Sandra, Mathew indicated that, “The school community thinks that teachers of RE should be at the centre of worship during assemblies because they teach about religions” and should always lead assemblies which he felt was not appropriate. He further complained that a wrong message is sent when RE teachers are expected to be the ones to start meetings and briefings, because such a practice might make students to think that RE teachers are examples of Christian models.

According to Becky’s statement that: “Before conducting an assembly, other teachers often approach RE teachers to seek advice regarding the passage to be read from the Bible”. Rita also observed that other teachers expected RE teachers to be well-versed in preaching and in the interpretation of the Bible.

Rita: Not all teachers are competent in Bible reading and its interpretation. RE teachers are made to feel uncomfortable, because they are forced to do what they never do in their lives. Someone who never goes to church cannot be competent in the content of Christian worship. Another bad thing is when some teachers ask their pupils to deliver the Bible message to other pupils during assembly.

**Awareness of the Withdrawal Clause**

Teachers were not aware of their rights in terms of conscientious objection to worship in school. Jakes observed that teachers were ignorant of the clause because they never think of opting out of a Christian inclined assembly. Kim also said that, Teachers are not even aware that it is against the constitution of Botswana to involve children in a worship activity without the consent of parents and guardians. Unfortunately, teachers do not know their rights. The point was also made by Becky who said that, “Teachers have to be sensitized about the law regarding religious instruction because most of them engage in worship out of ignorance”. Furthermore, teachers felt that unlike pupils who are minors and explicitly covered by the law, they are not clearly protected by the law, yet the school administration expects them to engage and lead in worship.

Mike: Statutes should state clearly the stand of teachers in connection with worship because with pupils it is clear that their parents may withdraw them yet nothing is said about the teachers. Currently, it seems some teachers conduct worship
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just because they want to please their supervisors. Sometimes, the manner in which some teachers conduct assembly says a lot about their attitudes towards worship. No parents or faith communities have ever questioned the act of worship in state schools.

It was also observed that parents were equally unaware of the withdrawal clauses in the Constitution and the Education Act.

Jakes: I have never heard of parents who withdrew their children from taking part in worship. This is because they are unaware of the withdrawal clause in the Education Act.

Kim: Students and parents are never asked if they accept worship and whether they are comfortable with a Christian based assembly which emphasizes the kingdom of God through Jesus Christ.

Kay: I do not know of any parent who knows about the withdrawal clause of the Education Act. Someone must sensitize parents on this issue. Furthermore, parents accept everything that the school administration says. Due to ignorance, some parents assume that it is an appropriate practice which is sanctioned by law, while others may know about the clause but would not want to voice it out due to fear that their children might be intimidated or discriminated against.

Becky and Kim observed that both teachers and parents were unaware of the withdrawal clause hence they needed to be sensitized about it. Rita was of the view that even though worship in schools is not compulsory and gives parents and guardians freedom to remove their children from such an activity they may not want to do so because that could have negative consequences on the child. She said that removing a child from school worship could isolate the child from the rest of the school community and make the child vulnerable to discrimination by both the teachers and students. What Rita said is in line with the thesis that religion and particularly Christianity has been given undue prominence over other social institutions. In this regard, the lack of identifying with Christianity makes students and teachers who are not Christians prone to isolation and discrimination.

Economic Status of Parents and Guardians

The low economic status of most parents and guardians was cited as another major factor, since they have no choice as to where they could send their children. Children from parents with a poor economic background attend public schools where fees are low and where worship is a practice.

Kay: In Botswana, many parents cannot afford to take their children out of the public schools which do not respect religious differences. The main reason being that, all government schools which offer almost free education, do practice worship, while the private schools which can be an option are expensive for ordinary citizens to take the child to. Parents who do not subscribe to Christianity remain helpless and leave their children to be indoctrinated in Christian values.

Worship as a Way to Enhance Morality

Despite of a strong voice from many teachers against worship, some felt that worship could enhance good morals in young children.

Moja: I do support worship in schools because it is one way of raising children in a disciplined manner. During worship, learners are taught good behaviors like the fear of God as well as good and acceptable behavior. Children are brought up through church life which can be very helpful to them. Worship can bring children together under one supreme body of Christ.

Mike: Worship is a good practice. Look, there has never been any chaos or riots in our schools due to religion like in other parts of the world. People here regard themselves as Christians because in most of their communal gatherings, such as weddings, different celebrations and parliament sessions, they perform Christian worship before they could start any of these events. Schools are, therefore, trying to align themselves with what the larger society is doing.
Matty: Pastors do a good job because they give words of encouragement and hope in times of doubt especially that people are faced with challenges of HIV and AIDS and natural disasters.

Jakes: The school administrators and government officials have this belief that Christianity can enhance positive attitudes in children. Many people in Botswana believe that Christianity can develop a sense of community spirit, promote common ethics and shared values. I have also observed that even during large communal or national celebrations such as Independence Day, the agenda will always start with a Christian prayer because most people believe that all events will go on smoothly and calmly if they start by connecting with God through prayer.

**Findings**

Several themes emerged some of which were teachers’ experiences about worship, the diverse nature of the school community, the influence of missionaries in education, teachers’ awareness of the withdrawal or conscience clause, low economic status of parents and guardians, worship as a way to enhance children’s morality and the inappropriateness of RE teachers to lead worship and alternatives to worship.

Teachers are aware that worship is still widely practiced in Botswana public schools. They are in agreement that it is an inappropriate practice in a society that is pluralistic and where government statutes are clear on freedom of conscience. However, teachers gave various reasons why worship in public schools is inappropriate. For example, they indicated that if it is forced on people, worship could demean the faith of the believers and render it a mockery. They further articulated that worship becomes hypocritical and a superficial act if teachers and students who are non-Christians make proclamations of a belief system that they do not hold dear. Furthermore, it is immoral for some students to participate in what is foreign to their belief systems while being denied the opportunity to exercise what they believe in and what they learnt at home from their parents. They further argued that formal education should not bring about conflict between what children learn at home and what is practiced in schools. They further observed that compulsion to worship runs against the democratic values of freedom and respect of individuals which schools may seek to promote.

Furthermore, RE teachers expressed discomfort when the school community expected them to be the appropriate people to lead worship at assembly. Even though there was disquiet among teachers, there were some ones who still felt that religion was necessary and should be an integral part of assembly as a necessary moralizing agent. Some of the teachers were of the view that worship may be serving an important purpose in terms of contributing towards the promotion of spiritual, moral and social development of students. Other teachers disagreed and argued that morality could be tapped from various sources and not from religion only and especially the Christian religion. Teachers indicated that students from low income parents and guardians are left without an option regarding where to attend school except in government schools where fees are low. Furthermore, teachers suggested several alternatives to conducting assembly among which are exposure to various religions at assembly and have a religiously free assembly.

**Conclusions**

Since assembly is compulsory in Botswana schools, worship renders non-Christian teachers and students captive converts and worshippers. The need to appreciate religious differences should be the goal of schools. Furthermore, public schools are supported by taxes of citizens from different religious affiliations and even from those who do not practice religion at all. Schools need to promote diverse ways in which young people make sense of the world by affirming their full humanity irrespective of their religious affiliation or lack of it. Assemblies need not be places where students are made to conform, but should be places where they make
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sense of themselves and other people’s cultures and personal behaviors. It is only then that students can have the capacity of being truly democratic citizens of their country and the world. Worship in schools marginalizes non-Christians and non-religious school personnel through institutionalized stereotyping. Non-Christians sacrifice their identity and self-worth, something that is recognized by the law in a subtle manner. This subtle acknowledgement of Christian supremacy is reinforced in the interest of Christians and at the expense of the subordinated non-Christians. In the Botswana context, there is a presupposition of unanimity of views regarding religious matters and assumptions are clear about the students’ and teachers’ religious commitments whereby Christian values are regarded as being common to all and capable of binding all members of the school community. The conventional wisdom in Botswana is to create an ethnically homogenous nation state in terms of culture including religion which is a distortion of a liberal democracy.

Furthermore, incorporating different religions in assembly may prove cumbersome and inappropriate, since such a move is capable of bringing about tensions in the school community. Consequently, different religions cannot be incorporated in one assembly as a way of satisfying them since that could lead to the emergence of factions and hatred in the school community since religions will be competing against one another for space and time. Lastly, strengthening of bonds and sharing of common values and experiences within an institution can still be enhanced through other means which may not necessarily be of a religious nature.

References
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Lisbona’s Goals and Bolonian Process-Issue of Education in EU Integration

Metod Černetič
University of Maribor, Kranj, Slovenia

Lisbona’s (2000) goals and strategy gave us the answers to the question how EU (European Union) can be competitive in the long term and, at the same time, preserve European model of life, that means a balance between economical, social and environmental goals. Knowledge is the focal point of development. That is the reason why many European states (and Slovenia too) strongly support the idea of construction of knowledge society which started with Lisbona’s goals and BP (Bologna process). The first condition for maintenance of social sustainability and kindness towards an environment is economical growth. The successful achievement of educational objectives depends largely on the successfulness of co-ordination among all parties concerned. The educational organizations have an objective among others to improve the quality and standard of education. They play an important role in the system of education. There is, by all means, an explicit need of co-ordination with the interested organizations from the environment which is an important element of their success. In this paper, we will deal with educational organizations, whose objectives will be defined from the point of view of their organizational aims which need to be attainable, coordinated, measurable and stimulating. Further, we will deal with policy and strategy of development of the organization. We will hypothesise that the objectives of education are derived from the human need for education and that is the reason why organizations are set up to satisfy this need. A further hypothesis will be that the objectives of all participants are both internal and external, economic, social (political) and psychological. We believe that individuals, organizations and state have many of these objectives in common but some of them, however, are not shared. The successfulness in satisfying the educational needs depends on the mutual co-ordination of all interested parties. The educational system is an open system where the changes happen on the levels of organization, society, culture and environment and on the level of external reform of education.

Keywords: Lisbona’s goals, BP (Bologna process), educational needs, social cohesion

Lisbona Goals and BP (Bologna Process)

Bologna Process and Higher Education

The BP major reform created with the claimed goal of providing responses to issues, such as the public responsibility for higher education and research, higher education governance, the social dimension of higher education and research, the values and roles of higher education and research in modern, globalized and increasingly complex societies with the most demanding qualification needs.

With the BP implementation, higher education systems in European countries are to be organized in such a
way that (Zgaga, 2009; as cited in Černetič, 2006, p. 314):

1. It is easy to move from one country to the other (within the European Higher Education Area)—for the purpose of further study or employment;
2. The attractiveness of European higher education is increased so that many people from non-European countries also come to study and/or work in Europe;
3. The European Higher Education Area provides Europe with a broad, high quality and advanced knowledge base and ensures the further development of Europe as a stable, peaceful and tolerant community benefiting from a cutting edge European Research Area;
4. There will also be a greater convergence between the US and Europe as European higher education adopts aspects of the American system.

**Effects of BP by State**

Contrary to popular belief, the BP was not based on an EU (European Union) initiative. It constitutes an intergovernmental agreement, between both EU and non-EU countries. Therefore, it does not have the status of EU legislation. Also, as the “Bologna Declaration” is not a treaty or convention, there are no legal obligations for the signatory states. The (extent of) participation and cooperation is completely voluntary. This can be regarded both as a positive and a negative thing. On the one hand, one could say that this bottom-up voluntary convergence does justice to the sovereignty of the states, which is especially important in the field of education. On the other hand, the avoidance of EU structures can be regretted for democratic reasons. The “Bologna Declaration” can be said to be a deal done in a smoke-filled room by governmental officials without any participation of the European parliament. Also, the involvement of the national parliaments has been limited (Haug, 2003, p. 221).

Although the “Bologna Declaration” was created outside and without the EU institutions, the European Commission plays an increasingly important role in the implementation of the process. The commission has supported several European projects (the tuning project, the TEEP (the teacher effectiveness programme) project) connected to quality assurance, etc. Most countries do not currently fit the framework—instead they have their own time-honored systems. The process will have many knock-on effects, such as bilateral agreements between countries and institutions which recognize each others’ degrees. However, the process is now moving away from a strict convergence in terms of time spent on qualifications towards a competency-based system. The system will have an undergraduate and postgraduate division with the bachelor degree in the former and the master and doctoral in the latter.

In mainland Europe, five year plus first degrees are common with some taking up to eight years not being unheard of. This leads to many not completing their studies and many of these countries are now introducing bachelor-level qualifications. This situation is changing rapidly as the BP is implemented.

Depending on the country and the development of its higher education system, some introduced ECTS (European credit transfer and accumulation system) and discussed their degree structures and qualifications, financing and management of higher education, mobility programmes, etc.. At the institutional level the reform involved higher education institutions, their faculties or departments, student and staff representatives and many other actors. The priorities varied from country to country and from institution to institution (Zgaga, 2009b, p. 67).
History of Integration Higher Education in EU

BP and EHEA (European Higher Education Area)

To give a general (and now in practice the most often used) description of recent processes in European higher education, we may use the term BP or the emerging EHEA. This new European higher education brand (Zgaga, 2004, p. 98) symbolized a whole set of important policy issues in higher education which have been broadly discussed at institutional, national and European levels since 1999. However, if we look more closely at some of these issues, it becomes obvious that the “Bologna agenda” has an important pre-history. The ideas presented in the “Sorbonne Declaration” of 1998 are its direct predecessor. Yet, these ideas were even emerging in previous debates—in preparing national policy responses to problems of the development of higher education and in comparing and confronting these responses (and the logic behind them) in a broader arena, such as within European Union consultation processes or within the Council of Europe and UNESCO as in the case of the “Lisbon Recognition Convention”.

These debates which would have been very different in having had a decision to enlarge the European Union or having the turbulent events seen in central and east Europe at the end of the 1980s, etc., do not occurred. The background is, thus, expanding. However, our task here is not to start writing a modern history of higher education in Europe which is about summarizing current trends in indifferent parts of Europe. At this point, however, it is necessary to define the turning point at which the issues and problems of modern higher education are rooted irrespective of national contexts. Recent literature reveals a high level of consensus that this turn is most closely linked to the transition from elite to mass higher education. Historically, in the developed countries, it occurred during the period of industrial growth after the Second World War. At the beginning of the 1970s, it was already clear that universities had entered a new era—but which era? The transition from elite to mass higher education involves a shift that we probably still do not understand in all of its dimensions.

The Dimensions of Mass Higher Education and Its Challenges

Thus, the expansion of higher education began during the 1960s. The increased demands for places at universities were a combined result of economic development and a higher number of candidates from the relevant age groups. The greater demand was clearly not some abstract arithmetic outcome. It was not only a simple response to growing employment options. It was also a result of the population’s higher social and cultural expectations. Despite the obvious fact that this expansion was driven by economic and political factors which were more or less common to various developed industrial countries of the West, there were clear differences in its national tempos. Behind the increase in particular countries, we can recognize special national circumstances, such as shifts in home politics, social and cultural backgrounds, particularities of the functioning of national higher education systems, etc..

Since the 1980s, changes in the economy, technology and the labor market have further reinforced the existing demand for higher-level training and at the turn of the millennium the academic landscape was totally different from that seen in the 1960s. In the so-called EU-15 countries, the number of students in higher education is more than doubled in the last quarter of the 20th century. A relatively moderate increase can be noticed in traditionally well-developed higher education systems (Germany, the Netherlands, Italy and France), while the highest increases are more characteristic for the “suburbs” (Portugal, Greece, Ireland and Spain)
and/or those countries which joined the EU at later stages.

The political changes in Central and Eastern Europe in the early 1990s brought about inter alia, an even more noticeable increase in the number of students in higher education. The relative delay of the 1970s and 1980s was more than compensated for during the 1990s in almost all of these countries. Europe got rid of its internal divisions, and today, it is somewhat easier to make comparisons. When we observe Europe in apolitically non-polarized and geographically broader context, the growth of student numbers in higher education slowed down in Western Europe—in a few cases, it was even negative: Belgium, Germany, France, Italy (Eurostat, 2003, pp. 90-91), whereas it achieved the highest peaks in central and eastern Europe (with the exception of Bulgaria). During the last decade of the 20th century, growth in student numbers is marked by an index of only 105 in the EU-15 and even 150 in the EU-10; and an integrated index for the EU-25 is 111.

Nowadays, Europe (and not just Europe) is being challenged by a population decrease, because there are fewer and fewer young people in almost all countries. The high enrolment ratios achieved during the last few decades will surely continue and even increase to over one-half of the relevant age group; on the other hand, the decrease in the young population is expected to reduce in absolute figures the demand for places in the (now extremely expanded) higher education sector. This shift will pose (in fact it is already posing) new challenges in addition to the already known challenges of mass higher education. At the turn of the millennium, at the entrance to the knowledge society, such expectations seem to have finally encompassed tertiary education. A historic shift is occurring in the second half of the 20th century. Tertiary education is replacing secondary education as the focal point of access, selection and entry to rewarding careers for the majority of young people (OECD (Organization for Economic Cooperation and Development), 1998, p. 20).

The reasons why people in the modern world decide to commence higher education differ considerably from the past. Nevertheless, we can still fully understand traditional individual aims like the “pursuit of truth” and “disinterested research” or a simple desire to join a profession (or continue a family tradition in practicing a profession) in order to help people care about their body, property or soul—while simultaneously gaining a highly recognized status in society. We can understand our predecessors but we also know that the specific social contexts in which our individual aims and wishes are formed in concrete ways have changed greatly since previous times. Rewarding careers (not for the minority but for the majority of young people) are today offered by advanced training.

Higher education is no longer primarily a personal call or privilege. It is a social demand that modern societies cannot function without increasing the number of educated and skilled people who work in the economy and public services or without expanding the research and knowledge that drive modern civilization. The increasing numbers of students led to criticisms by (not only) teachers regarding falling standards and today’s students alleged ignorance. The growth in student numbers was not being accompanied (at least not proportionally) by new teachers. Nevertheless, today there are many more teachers (and many more new higher education institutions) than before but there is also a new popular discourse concerning “excellent”, “average”, “poor” or even “scandalous” teachers and institutions. Yet, these complaints should stem from students not academics! Were universities ready to cope with the challenges of mass higher education when they started to appear? Obviously not! The new situation was quite a surprise for everybody.

Over several years, (some) people understood that the world had changed and that the university is in a position to reconsider its mundane mission. The “splendid”, “optimal” but closed and isolated universe of the ivory tower could be just a myth. If one-third of an age cohort comes instead of 2% then there are not only
“born talents” among them. However, they all deserve active and quality teaching and we should not just wait to see who will succeed and who will be left in the field. It is excellent if the need to know has spread so much! Today, if the government seeks higher enrolment levels and new study programmes with an emphasized vocational dimension for the sake of improved employability and general welfare, then rectors should consider this with due attention. Finally, it would not be in line with academic traditions if they did not hear voices outside closed towers: a part of these traditions has been able to serve society. Modern university is not a monastery. As the “pursuit of truth” might sound a little “transcendent”, the university as a place of learning and research has always been open and connected to society in certain ways. Modern theories on university and higher education institutions generally distinguish between their several genuine roles or tasks. To undertake research and teaching, that is (Zgaga, 2003, p. 108):

1. To maintain and develop an advanced knowledge base;
2. To train—the young and the not so young—people for their professional careers;
3. To prepare them for a life as active citizens in a democratic society;
4. To contribute to their personal growth.

On the other hand, since mass higher education emerged numerous writers have been stressing that academic institutions should be responsive to society. This is absolutely correct, yet it is only half of the truth. Precisely for the multiple roles they play in culture and society, today academic institutions should not only be responsive (receptive) but also responsible (pro-active) (Weber, 2002, pp. 62-63):

While responding to society’s needs and demands, universities have also to assume a crucial responsibility towards society… The great difference between being responsive and being responsible lies in the fact that in the first case, universities should be receptive to what society expect from them; in the second case, they should have an ambition to guide reflection and policy-making in society. While universities excel at making new discoveries in all disciplines of science and technology, they must also scrutinize systematically the trends that might affect soon or later the well-being of populations, and, if necessary, raise criticism, issue alarm signals and make recommendations.

Universities and External Purposes

Universities do not exist just for some external purposes; and they are (also) a legitimate place to reflect them. Further, reflecting changes in higher education, coping with the challenges of mass higher education, taking part with other institutions in policy analysis and acting with stakeholders is all part of their mission. Higher education has become a recognized field of research because it is an equally important area for external society, as it is for academic institutions themselves. Academics should also deploy their own intellectual resources to take stock of modern changes seen in higher education, the dimensions of internationalization and its challenges to higher education policy. A review of the past few decades shows that the expanding tertiary education sector (in particular the democratizing and liberalizing of access) put the need for systemic reforms firmly on national and institutional agendas. A few years ago, the Eurydice network produced a very useful study of reforms in European higher education in the 1980s and 1990s (Eurydice, 2000; as cited in Zgaga 2009a, p. 10) which provides an insight into these processes at an international level and which we will also draw upon here.

This comparative study allows an insight into systemic changes among the reviewed 18 European countries. In all countries, policy and legislative activities were particularly condensed at the end of the 1980s and in the 1990s. They show a large number of convergent trends in higher education among individual countries but the study states that:
There is no evidence that these developments were the result of a concerted approach between participating countries. The convergent education policies seem more likely to be a by-product of the economic and social policies which, in the context of European integration, underwent a deliberate harmonization process. (Eurydice, 2000, p. 174)

This statement seems a little surprising from today’s point of view that the convergent education policies are just a by-product! Within the EU-25 action Education and Training 2010, an OMC (open method of co-ordination) established (Commission, 2001, p. 14).

In the perception of many generations, European universities have predominantly been national universities. This perception may vary according to national circumstances and levels of influencing and co-operating with other countries and universities. Nevertheless, in the 20th century we experienced (national) borders between (national) higher education systems and sometimes even between national institutions. Yet, there were no geographical, political and/or institutional barriers for universities in the middle ages. National (higher) education systems were born parallel to the industrialization processes in modern national states. As a sub-chapter to the protection of domestic markets, protective measures in the field of (higher education) qualifications emerged and various recognition procedures (predominantly for professional recognition) were put in place. However, due to the universal character of science and culture as well as centuries-long academic traditions certain compatible elements persisted throughout the otherwise incompatible national systems. Universities continued to co-operate in the given circumstances and the given extent, and students still went to study abroad but both institutions and individuals encountered many obstacles for either economic or ideological reasons (or both).

**Criticism of BP**

“Anti-Bologna” demonstrated in Barcelona, Spain, 2008. The process has been criticized because it would allow privatization of the degrees.

The new changes were closer to the UK and Ireland’s models than that used in most of Continental Europe. In many countries, the process was not implemented without criticism.

**Economic Aspects**

There is much skepticism and criticism of the Bologna process from the side of academics. Thus, Lorenz (2003) has argued that (as cited in Zgaga, 2005, p. 110):

The basic idea behind all educational EU-plans is economic: the basic idea is the enlargement of scale of the European systems of higher education ... in order to enhance its “competitiveness” by cutting down costs. Therefore a Europe-wide standardization of the “values” produced in each of the national higher educational systems is called for.

Just as the World Trade Organization and GATS (general agreement on trade in services) propose educational reforms that would effectively erode all effective forms of democratic political control over higher education, so it is obvious that the economic view on higher education recently developed and formulated by the EU Declarations is similar to and compatible with the view developed by the WTO and by GATS.

**Academic Aspects**

In much of continental Europe, the previous higher education system was modeled after the German system, in which there is a clear difference of vocational and academic higher education. This mostly has an impact on the old engineer’s degrees. The conflation of the two types of degrees can be counter-productive in the following cases (Zgaga, 2009a, p. 11):
(1) The vocational three-year degrees are not intended for further study, so those students who also want to advance to a master’s degree will be at a disadvantage;

(2) The master’s degree effectively becomes the minimum qualification for a professional engineer, rather than the bachelor’s degree;

(3) The academic three-year degrees prepare only for continuing towards master’s, so students who enter the workforce at that point will not be properly prepared. Yet, they would have the same academic title as the fully trained and vocationally educated engineers (see Fachhochschule).

The end-result of the change is that the agreements between professional bodies will require reevaluation in some cases as qualifications change.

Other Reforms as Riders of BP

The Bologna process has been implemented concurrently with other reforms, which have been attached as “riders” to the implementation itself. These reforms go far beyond the minimum provisions necessary to implement the Bologna process including introducing tuition fees, overhauling departments and changing the organization of universities. These reforms have been criticized as unnecessary and detrimental to the quality of education, or even undemocratic.

For example, in Finland, the official goal was to improve students’ performances and enable them to gain diplomas faster by introducing stricter standards. However, students feel that the workload has increased and the new standards lead to a micromanaged and too narrow curricula (so-called putkitutkinto). The Bologna process is said to lead to universities being “diploma factories”. Also, for example at ECTS, most students (85%) fail to achieve the official goal of 120 credits in two years—the average is 81 credits. The number of students failing to achieve the minimum credits to receive student benefit has risen 40% following the implementation of the process.

The part of the explanation is that student’s life in Finland tends ample extracurricular activities. The silent agreement has been the gain in life experience and extended personal networks more than makes-up for the increased study time. Because these personal networks include alumni in influential positions, students have long been able to resist attempts to improve their nominal studying performance by the sacrificing extracurricular activities. The Bologna process as a pan-European effort has extended over and above these student/alumni networks.

Four Avenues of Improvement BP

One of the authors of the Bologna process (Haug, 2003, p. 213) said that the Bologna process has sometimes become a focus of tension, with institutions perceiving their government as being more interested in the rhetoric of reform than in providing genuine support to institutions.

First Aveny

FQ EHEA (framework qualification European higher education area) (Bergen, 2005) indicated that credits and qualifications are described in terms of learning outcomes, levels and associated workloads. Workload is defined as a quantitative measure of all learning activities that may feasibly be required for the achievement of the learning outcomes (e.g., lectures, seminars, practical work, private study, information retrieval, research and examinations). The feasibility of attaining the learning outcomes required for credit within programmes is important for the credibility of the framework and its helpfulness to learners. Timetable with credit evaluation
of studying obligation has to be considered that: 1 CP (credit point) means 25-30 hours load per student; yearly load is 1,500-1,800 hours; individual year include 60 CP, etc.

A part-time study indicates that in what proportion (in relation to the regular studies) will be carried out by organized forms of pedagogical work (from the suggestions in the process).

Information on the methods and forms studies: program cannot take more than three years, including part-time study! What is our “part-time”, “part time study” or perhaps “extraordinary study”? How to get regular and part-time in the Fund with the “spirit” (and not just form) ECTS? (Website http://docs.google.com/gview?a=v&attid=0.1&thid=11f5c435d1d9fa07&mt=application%2Fpdf)

Second Avenue

The second avenue is as shown in Figure 1.

![Second avenue: Assuring quality in EVP](http://www.cmepius.si/files/cmepius/userfiles/dogodki/drZgaga_posvet040209.pdf)

**Third Avenue.**

**Official status.** Agencies should be formally recognized by competent public authorities in the EHEA as agencies with responsibilities for external quality assurance and should have an established legal basis.

**Third Avenue.** SGQA (survey/group/question/answer) EHEA (Bergen, 2005)

**Independence.** Agencies should be independent to the extent that they have autonomous responsibility for their operations and that the conclusions and recommendations made their reports cannot be influenced by third parties, such as higher education institutions, ministries or other stakeholders.

**Art. 48.** Government of RS (Republic of Slovenia) set up a Council of the Republic of higher education as a consultative, accreditation, evaluation and habilitation authority of RS. Council is to carry out their duties and decision-making autonomy. All decisions are in acceptance of independent, professional and impartially.

**Art. 50.** Professional, organizational and administrative duties for the council are carried out by the body within the ministry responsible for higher education. Individual tasks may be awarded to external contractors.
Constitutional Court (Jan. 2008). The eighth paragraph of 50. Article shall be annulled.

Fourth Aveny

Independence. Agencies should be independent to the extent both that they have autonomous responsibility for their operations and that the conclusions and recommendations made their reports cannot be influenced by third parties, such as higher education institutions, ministries or other stakeholders (Website http://docs.google.com/gview?a=v&attid=0.1&thid=11f5e435d1d9fa07&mt=application%2Fpdf) (see Tables 1 and 2).

Table 1

Top 10 Erasmus Teachers Mobility 2004/2005

<table>
<thead>
<tr>
<th>Top 10 Movers</th>
<th>Top 10 Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malta</td>
<td>Malta</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Finland</td>
</tr>
<tr>
<td>Finland</td>
<td>Slovenia</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Cyprus</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Belgium</td>
</tr>
<tr>
<td>Estonia</td>
<td>Latvia</td>
</tr>
<tr>
<td>Latvia</td>
<td>Czech Republic</td>
</tr>
<tr>
<td>Belgium</td>
<td>Iceland</td>
</tr>
<tr>
<td>Iceland</td>
<td>Portugal</td>
</tr>
<tr>
<td>Cyprus</td>
<td>Lithuania</td>
</tr>
</tbody>
</table>


Table 2

Foreign Tertiary Student in Euro Data and Europe

<table>
<thead>
<tr>
<th>EURODATA countries</th>
<th>All tertiary students</th>
<th>All foreign students</th>
<th>Foreign (%)</th>
<th>Euro data countries (%)</th>
<th>Other European (%)</th>
<th>Non-European countries (%)</th>
<th>10 most frequent nation. of students (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT Austria</td>
<td>229,802</td>
<td>31,101</td>
<td>13.5</td>
<td>74.6</td>
<td>13.3</td>
<td>11.7</td>
<td>97.1</td>
</tr>
<tr>
<td>CZ Czech Rep.</td>
<td>287,001</td>
<td>10,338</td>
<td>3.6</td>
<td>77.0</td>
<td>8.9</td>
<td>12.3</td>
<td>82.0</td>
</tr>
<tr>
<td>DK Denmark</td>
<td>210,746</td>
<td>18,120</td>
<td>9.0</td>
<td>36.9</td>
<td>6.3</td>
<td>42.4</td>
<td>38.3</td>
</tr>
<tr>
<td>EE Estonia</td>
<td>63,625</td>
<td>1,090</td>
<td>1.7</td>
<td>75.1</td>
<td>11.2</td>
<td>13.7</td>
<td>94.8</td>
</tr>
<tr>
<td>FI Finland</td>
<td>291,664</td>
<td>7,361</td>
<td>2.5</td>
<td>38.4</td>
<td>17.3</td>
<td>42.4</td>
<td>58.5</td>
</tr>
<tr>
<td>GR Greece</td>
<td>561,457</td>
<td>12,456</td>
<td>2.2</td>
<td>84.9</td>
<td>8.3</td>
<td>6.3</td>
<td>92.5</td>
</tr>
<tr>
<td>HU Hungary</td>
<td>390,453</td>
<td>12,226</td>
<td>3.1</td>
<td>63.7</td>
<td>20.9</td>
<td>15.5</td>
<td>84.6</td>
</tr>
<tr>
<td>LV Latvia</td>
<td>118,944</td>
<td>2,390</td>
<td>2.0</td>
<td>29.4</td>
<td>15.4</td>
<td>55.2</td>
<td>93.2</td>
</tr>
<tr>
<td>NL Netherland</td>
<td>526,767</td>
<td>20,531</td>
<td>3.9</td>
<td>57.8</td>
<td>3.5</td>
<td>38.0</td>
<td>70.0</td>
</tr>
<tr>
<td>SE Sweden</td>
<td>414,657</td>
<td>32,469</td>
<td>7.8</td>
<td>53.7</td>
<td>4.6</td>
<td>20.0</td>
<td>44.9</td>
</tr>
<tr>
<td>SI Slovenia</td>
<td>101,458</td>
<td>963</td>
<td>0.9</td>
<td>11.2</td>
<td>83.8</td>
<td>3.1</td>
<td>92.9</td>
</tr>
<tr>
<td>SK Slovakia</td>
<td>158,089</td>
<td>1,651</td>
<td>1.0</td>
<td>39.4</td>
<td>25.0</td>
<td>35.6</td>
<td>72.0</td>
</tr>
<tr>
<td>Total</td>
<td>19,430,382</td>
<td>1,117,725</td>
<td>5.8</td>
<td>42.1</td>
<td>8.0</td>
<td>45.6</td>
<td>56.8</td>
</tr>
</tbody>
</table>


A Few Remarks and Some Questions for Reflection

This paper presents an analysis of some trends in contemporary higher education and aims at providing a broader context for the conference entitled “Tertiary Education: Quality, Financing and Linkages with Innovation and Productivity”. Like any paper of this kind it is limited in scope and size. Many notes are
intended for readers who would like to examine in detail particular issues, statements and information sources. The bibliography and some figures in the annex have the same intention to allow deeper insights and further study. Finally, a few questions aim at a recapitulation and connecting the trends observed as well as statements presented in the paper with the objectives of the conference and the background materials (e.g., reports from previous workshops). They also aim at stimulating reflections about the issues raised and consulting other papers produced for the conference and during previous workshops. Since a special website will be set up prior to the conference, at least some of the reflections, questions and comments can be exchanged before the participants meet in October. The questions are as follows:

1. Mass higher education has had a different time schedule in different parts of Europe. What are main stages in the development of mass higher education and what are main policy challenges at particular stages?

2. The internationalization of higher education is today a fact. The main drivers of these developments are attributed to economic and social policy as being external to the higher education sector. Are there also internal drivers (inherent to the nature of higher education and its traditions) that can stimulate internationalization? How does the internationalization of higher education also stimulate the internationalization of higher education policy?

3. It is often stressed that compatible qualification structures as well as quality assurance standards and procedures in higher education should enhance the employability of graduates and increase innovation and productivity. It has been stressed in discussions that broader changes to education systems (not only at the tertiary level) are needed as well as changing the mindset (e.g., Workshop in Riga, 2005; as cited in Zgaga, 2005). How can higher education as the top of the education pyramid help in improving the lower levels (e.g., teacher training, popularizing science and technology, etc.) as well as itself?

4. The review of trends in higher education showed that the issues of financing higher education systems are not likely to be included in official international documents, e.g., the Bologna Communiqués. On the other hand, recent discussions (Workshop in Warsaw, Riga and Bratislava, 2005; as cited in Zgaga, 2005) have shown that this issue is the most relevant one and that the international consultation and exchange of good practices is very stimulating. Which obstacles have meant that financing issues have not been included (or very rarely) in multilateral political documents as more binding statements? Would their inclusion be at all helpful?

With few exceptions, European higher education systems have traditionally been very influenced by the state. Since the 1980s, this role has started to change that the state has been withdrawing from direct institutional governance. The state’s influence started to be restricted to setting general higher education objectives (structures and qualifications) that is, to higher education output (graduates, their employability, etc.) and not to the process. As a rule, legislative provisions were redirected from funds allocated to institutions strictly by budget lines (salaries, equipment, maintenance, etc.) to the allocation of block grants aiming to increase autonomy for its financial dimension.

This is the conceptual turn—a move away from the traditional intervention towards the new facilitator state (Neave & Van Vught, 1991; as cited in Zgaga, 2005, p. 114) which is the most characteristic feature of the policy and legislative changes of the 1980s and 1990s and still retains some relevance today. Institutions got more autonomy but they became more accountable: They are bound to the more efficient use of public funds and encouraged to seek alternative sources and to be more open to the economy and society. A special tool for and proof of institutional accountability has been given by developing and implementing QA methods in higher education. A preliminary result of national developments in this area was the extreme variety of QA provisions
at the beginning of the 1990s. It seems this variety was even larger than that in the case of degree structures. Interestingly, the issue of quality assurance was not an item on the agenda of the Memorandum on Higher Education in the EC (Commission, 1991; as cited in Zgaga, 2005, p. 115).

However, the spirit of European co-operation in higher education well supported during this period by EU member countries and positively influencing the broader European context as well, sparked discussions among countries even in this area. An early EU document stressing quality assessment in higher education was only adopted in late 1991 (Zgaga, 2005, p. 117):

> Improving the quality of teaching in higher education is a concern shared by each member state and every institution of higher education within the European communities. The increasing importance of the European dimension in general and more particularly the introduction of a single market will widen the range of interested parties concerned with quality in higher education in each Member State.

Encountering the diversity (or absence in some national systems) of methods used for quality assessment at the national level, the document also stated that it would accordingly be useful for the methods at present used in the Member States for quality assessment in higher education to be investigated in a comparative study.

**On the Grounds of Innovation and Productivity**

The overarching framework of qualifications and European standards and guidelines has similar logics and supplement each other. They reflect and synthesize numerous previous discussions; they refer to the logic of the higher education developments of the last decades. They mark an important landmark in the internationalization of higher education but they should not be treated as completed. The challenges brought by the development of mass higher education in the global environment are huge to make diverse systems comparable and compatible and promote mutual trust by creating quality culture, while at the same time, the diversity of national contexts, as well as subject areas, should be fully respected. This is a demanding agenda, but contemporary trends in all countries persuade us that different independent national frameworks, which are not linked together in a coherent way, would not fulfill the learners’ expectations of a European Higher Education Area of transparency and mobility where qualifications are easily recognized across borders. … In order to facilitate fair recognition it is necessary for foreign partners to trust that national qualifications also in practice correspond to the levels to which they are attached. In this context, the quality assurance system, however it is organized nationally, has a role to play (Zgaga, 2005, p. 113). Effectiveness as well as innovation and productivity are today expected from higher education: for good reasons.

However, higher education (responsive and responsible) cannot consider innovation and productivity only as external purposes and it (with institutions as the system) should be innovative and productive for itself, internally, searching for a new identity to meet the new challenges. There have been progressive periods and deep crises in the history of European universities. Experience proves that they undertook immense forward steps when they found innovative and productive responses to challenges of the time whereas persisting in the old forms and discourses did not help. We should learn from these lessons. Neither the unlimited commercialization of higher education and research nor the dignified contempt of academic traditionalism can yield truly innovative and productive answers to the key questions of our time. An understanding of these questions should not be caught within the circle of opposite complaints like “there are never enough financial resources for higher education institutions” or “dropout levels from higher education are always too high”. Higher education today and tomorrow is not only more or less than yesterday and the day before; if it comes to
a turning point between the previous and the current then it is different. Therefore, the effectiveness of higher education should not only be understood as a quantitative entity, but also qualitative. We should be aware that treating ideas only instrumentally render sterile the soil of human intellect; yet, we should not forget that ideas are sterile if they do not provide in their final results for new instruments to help people and society. At this point, real innovation and productivity have always found firm grounds.

Conclusions

The latest report on implementation of the BP warned that not all objectives will be fulfilled integrally and/or in all countries by 2010. One area where insufficient achievements require vigorous actions in the coming years is introducing lifelong learning into higher education. Slovenia would like to attract an in-depth discussion on the role and possible input of higher education to the concept of lifelong learning with the view of making further progress in this important area.

Higher education partners agree that Europe needs modernized universities, if it hopes to attain the objectives of the Lisbon Strategy, as universities are a key element of the knowledge triangle and, consequently, of a knowledge-based society. Modernizing universities is based on three pillars: autonomy and responsibility, administration and management and financing.

All three of them call for urgent changes. Slovenia will focus on the issue of whether Europe’s universities, on facing greater autonomy and requirements for greater responsibility, are capable of responding successfully to new challenges and tasks. In this regard, opinions will be exchanged as to whether Europe’s universities have proper governance and management structures in place.

This paper presents an analysis of some trends in contemporary higher education and aims at providing a broader context for the conference entitled “Tertiary Education: Quality, Financing and Linkages with Innovation and Productivity”. Like any paper of this kind it is limited in scope and size. Many notes are intended for readers who would like to examine in detail particular issues, statements and information sources.

Finally, the few questions listed above aim at a recapitulation and connecting the trends observed as well as statements presented in the paper with the objectives of the conference and the background materials (e.g., reports from previous workshops). They also aim at stimulating reflections about the issues raised and consulting other papers produced for the conference during previous workshops.

References

Salamanca and Prague Conferences of March/May 2001 (p. 91). Finnish National Board of Education, European Commission, Association of European Universities (CRE), ETF.


http://docs.google.com/gview?a=v&attid=0.1&thid=11f5c435d1d9fa07&mt=application%2Fpdf).


tenicoq.html.
Detecting a Gender-Related DIF Using Logistic Regression and Transformed Item Difficulty

Nabeel Abedlaziz, Wail Ismail, Zaharah Hussin
University of Malaya, Kuala Lumpur, Malaysia

Test items are designed to provide information about the examinees. Difficult items are designed to be more demanding and easy items are less so. However, sometimes, test items carry with their demands other than those intended by the test developer (Scheuneman & Gerritz, 1990). When personal attributes such as gender systematically affect examinee performance on an item, the result can be DIF (differential item functioning). The purpose of this study was to examine gender differences in performance on multiple-choice mathematical ability test, designed to match six grade curriculums. The LR (logistic regression) method and transformed item difficulty were used to detect a gender related DIF. A random sample of 800 tenth grade students was selected. DIF analysis indicated that: (1) Females showed a statistically significant and consistent advantage over males on numerical ability, whereas men showed a consistent advantage over females on spatial ability and deductive ability; (2) The percentage of agreement between the two approaches in detecting DIF is relatively low; and (3) Gender differences in mathematics may well be linked to content.

Keywords: DIF (differential item functioning), transformed item difficulty, LR (logistic regression), mathematical ability

Introduction

Standardized tests and measurements are used primarily to distinguish between ability levels of examinees. As a part of the determination of validity for these tests, differential item analysis is employed to evaluate the degree to which measurements distinguish true abilities among examinees in an unbiased manner. Psychometricians and test developers use DIF (differential item functioning) analysis to determine if there is a possible bias in a given test item. DIF is determined in a two-step process. The first step is the comparison of two groups’ outcome on an item and determining the presence of DIF. The second step includes a decision of whether there is a large enough difference between the groups to eliminate or change the item of interest.

DIF is said to be present when examinees from different groups have differing probabilities of success on an item after controlling for overall ability (Clauser & Mazor, 1998). If an item is free of bias, responses to that item will be related only to the level of the underlying trait that the item is trying to measure. If item bias is present, responses to the item will be related to some other factors as well as the level of the underlying trait (Camilli & Shepard, 1999). The tight relationship between the probability of correct responses and ability or
trait levels is an explicit assumption of IRT (item response theory) (Hambelton, Swaminathan, & Rogers, 1991) and an implicit assumption of classical test theory (McDonalds, 1999). The presence of large numbers of items with DIF is a severe threat to the construct validity of tests and the conclusions based on test scores derived from items with and items without DIF.

Test items with content bias may: (1) contain content that is differentially familiar to matched groups of examinees; (2) contain sources of difficulty that are irrelevant to the construct adversely affecting test performance; (3) contain material that may be offensive, demeaning, or emotionally charged which can lower examinees’ motivation and attention for the remainder of the test, thereby, decreasing performance on other questions apart from the offending items; and (4) ask for information that students have not had equal opportunity to learn. Test items with gender bias may contain: (1) tasks which perpetuate undesirable role stereotypes, race stereotypes or gender stereotypes; (2) materials or references that may be offensive to members of one gender; and (3) references to objects and ideas that are likely to be more familiar to men or to women (Pedrajita, 2009).

Several techniques have been promulgated for the statistical assessment of DIF. Several excellent reviews are available (Clauser & Mazor, 1998; Camilli & Shepard, 1999; Millsap, 1993). Most techniques for DIF assessment has been developed in educational settings in which items are generally dichotomously scored as correct or incorrect.

Methods for detecting DIF have proliferated and have been reviewed in recent years. The various methods include techniques that tested differences in relative item difficulty among different groups, differences in item discrimination among different groups, differences in the ICCs (item-characteristic curves) for different groups, differences in the distribution of incorrect responses for various groups and differences in multivariate factor structures among groups.

A number of approaches have used item difficulty as the focus of analysis. An item is considered biased in this approach if, compared to other items on the test, it is relatively more difficult for one group than for another. One of the more widely implemented techniques of this type is TID (transformed item difficulty). LR (Logistic Regression) is based on transforming data by taking their natural logarithms so as to reduce nonlinearity. In other words, LR uses the logistic curve that best approximates the distribution of the data. LR estimates parameters using maximum likelihood estimation (Pedrajita, 2009). LR has been known for some time to be useful for the assessment of effect modification in observational studies and enables analyses of continuous predictor variables without requiring stratification. Not surprisingly, simulation studies from educational testing experts have found that LR-based DIF detection techniques enables the detection of both uniform and non-uniform DIF. Uniform DIF is said to apply when differences between groups in item of responses are found at all trait levels, while in non-uniform DIF an interaction is found between trait level, group assignment and item responses (Camilli & Shepard, 1999; Jodin & Gierl, 2001).

Gender Differences in Mathematics

In the past few decades, research has repeatedly reported gender differences in mathematics performance on a number of standardised mathematics tests such as the SAT-M (Scholastic Assessment Test-Mathematics) (Gallagher, 1990, 1992; Gallagher & DeLisi, 1994; Willingham & Cole, 1997; Hyde, Royer, Tronsky, Chan, Jackson, & Marchant, 1999). The test scores on these standardized tests have been regarded as an important measure of abilities to do mathematics problems (Casey, Nuttall, Pezaris, & Benbow, 1995; Halpern, 2000;
DETECTING A GENDER RELATED DIF

Stumpf & Stanley, 1998). But results from these studies are not consistent: Some found that males generally outperformed females on mathematical tasks (Maccoby & Jacklin, 1974; Fennema & Carpenter, 1981; Halpern, 2000); some showed different sizes of gender differences with respect to types of mathematical tasks (D. Voyer, S. Voyer, & Bryden, 1995). Hyde, Fennema and Lamon (1990) suggested that there was very small or null gender difference in mathematical ability on these tests. T. B. Caplan and P. J. Caplan (2005) even argued that the link between gender and the mathematical ability was very weak.

Battista (1990) conducted a study among 145 high school geometry students from middle-class communities. This research examined the role that spatial visualization and verbal-logical thinking played in gender differences in geometric problem-solving in high school. The findings suggested that males and females differed in the level of discrepancy between spatial and verbal abilities.

Gallagher, De lisi, Holst, McGillicuddy-De Lisi, Morely, and Cahalan (2000) suggested that males tended to be more flexible than females in applying solution strategies. Kessel and Linn (1996) and Gallagher (1998) reported that females were more likely than males to adhere to classroom-learned procedures to solve problems, so they might be less likely to use shortcuts and estimation techniques for solving unfamiliar and complex problems quickly.

Current education reform in general and mathematics education reform in particular emphasize the importance of thinking, understanding, reasoning and mathematical ability in students’ learning (e.g., NCTM (National Council of Teachers of Mathematics), 1989, 1991, 2000; National Research Council, 1989). Such reform effort in mathematics curriculum and instruction requires examination of male and female students’ thinking, reasoning, problem-solving and mathematical ability rather than merely computation and symbol manipulation. This study provided an opportunity to examine issues in mathematics learning in general and issues in gender-related differential item functioning of mathematical ability in specific.

Purpose

This study aimed to detect DIF of mathematics ability test. This study can significantly contribute to educational research. Test experts and developers may: (1) gain insights on the applicability of DIF detection method(s); (2) realize the validity of DIF methods in detecting a gender biased test items; (3) use DIF methods in developing valid and equitable tests; and (4) employ DIF methods in purifying their assessment instruments.

This study sought answers to the following questions: To what extent do the two methods (i.e., transformed item difficulty and LR) agree or disagree in detecting a gender-related DIF? A second question was: What is the nature of cognitive ability of those items identified as revealing DIF? A third question was: Are gender differences linked to content areas within mathematics?

Method

Participants

A total of 800 (380 males and 420 females Grade 10) students in Jordan were targeted as participants in this study at the end of the first semester in the school year of 2009-2010.

Instrument

A mathematical ability scale was developed as a part of this study. The scale compressed of 30 multiple-choice items to measure three components of mathematical ability (i.e., numerical ability, deductive ability and spatial ability). Psychometric properties of the test reveal some items needing revision. Nonetheless,
Detecting a gender related DIF

Reliability is reported KR (Kuder-Richardson)-20 indices to be 0.91. Spearman-Brown correction on split-half reliability for odd even comparison also show similar results \( r = 0.89 \). Validity of the instrument was shown using inter-correlation of the scale (0.19 to 0.855). Factor analysis reveals that the test measure one trait (unidimensionality).

**Logistic Regression (LR)**

Swaminathan and Rogers (1990) applied the LR procedure to DIF detection. This was a response, in part, to the belief that the identification of both uniform and non-uniform DIF was important. The strengths of this procedure are well documented. It is a flexible model-based approach designed specifically to detect uniform and non-uniform DIF with the capability to accommodate continuous and multiple ability estimates. Furthermore, simulation studies have demonstrated comparable power in the detection of uniform and superior power in the detection of non-uniform DIF compared to the MH (Mantel-Haenszel) and SIB (Simultaneous Item Bias) test procedures (Rogers & Swaminathan, 1993; Swaminathan & Rogers, 1990). These studies also identified two major weaknesses in the LR DIF procedure: (1) the Type I error or false positive rate was higher than expected; and (2) the lack of an effect size measure.

LR has a formal mathematical equivalence to the log linear model approach of Mellenbergh (1982): Coefficients for group, total score and interaction terms are estimated and tested for significance with a model comparison strategy. However, LR is highly similar to standard ordinary least squares regression. It can be conceptualized as an equation that uses group, ability and group-by-ability terms to predict whether an item response is right (1) or wrong (0). This property is desirable for didactic purposes.

LR uses the examinee as the unit of analysis and has the following form:

Where:

- \( g \): represents group membership (0 for focal group (female) and 1 for reference group (male)).
- \( x \): the matching group (the observed total test score).
- \( u \): represents the item response value (0 for an incorrect answer and 1 for correct answer).
- \( xg \): represents the interaction between the matching variable and the group variable..
- \( \beta_0 \), \( \beta_1 \), \( \beta_2 \) and \( \beta_3 \): parameters to be estimated.

The above equation is used for predicting the probabilities of correct and incorrect responses to each dichotomously scored item, given an observed total test score and its associated group membership. Once the estimates of the four coefficient parameters, \( \beta_1 \), \( \beta_2 \) and \( \beta_3 \), for an item are obtained from a sample of test responses, the usual likelihood ratio chi-square tests of significance of the estimates of are conducted to examine if DIF exist. The null hypothesis is that \( \beta_2 = \beta_3 = 0 \). An item shows uniform DIF if \( \beta_2 \neq 0 \) and \( \beta_3 = 0 \) with one degree of freedom and non-uniform DIF if \( \beta_3 \neq 0 \) (whether or not \( \beta_2 = 0 \)) with 1 degree of freedom (Swaminathan & Rogers, 1990).

In the present study, the item reveals uniform DIF when the significant odd ratio is for the group, whereas the item reveals non-uniform DIF when the significant odd ratio is for the interaction between the group and total score. The item reveals DIF in favor of males when the significant odd ratio is greater than one, whereas the item reveals DIF in favor of females when the significant odd ratio is less than one (\( \alpha = 0.05 \)).

**Transformed Item Difficulty (TID)**

Angoff (1972) offered the delta-plot or TID method which involves computing the difficulty or \( p \)-value
(proportion of subjects getting item right) for each item separately for each group. Using tables of the
standardized normal distribution, the normal deviate \( z \) is obtained corresponding to the \((1-p)\) the percentile
of the distribution, i.e., \( z \) is the tabled value having proportion \((1-p)\) of the normal distribution below it. Then to
eliminate negative \( z \)-values, a delta value is calculated from the \( z \)-value by the equation \( \Delta = 4z + 13 \). A large
delta value indicates a difficult item. For two groups, there will be a pair of delta values for each item. These
pairs of delta values can then be plotted on a graph, each item represented by a point on the graph. A Line can
be fitted to the plot of points and the deviation (distance) of a given point from the line is taken as measure of
that item’s bias, large deviations indicating much bias. In the present study, the distance that each point deviates
from the major axis of the ellipse was calculated. The equation used for the major of the ellipse was \( Y = AX + B \)
(the best fitting line) in which: \( Y \) represents males delta values (\( \Delta_M \)), \( X \) represents females delta values (\( \Delta_F \)), and:

\[
B = \mu_x - A \mu_y
\]

Where:

- \( A \): Represents a line slope;
- \( B \): The line sector of \( Y \)-axis;
- \( \mu_y \): The mean of delta values for females (\( \Delta_F \)),
- \( \mu_x \rightarrow \) The mean of delta values for males (\( \Delta_M \)); and

\[
A = \frac{(\sigma^2_y - \sigma^2_x)^2 + 4r_{xy} \sigma^2_y \sigma^2_x}{2r_{xy} \sigma^2_y \sigma^2_x}
\]

Where:

- \( \sigma_x \): The standard deviation of the deltas for males group;
- \( \sigma_y \): The standard deviation of the deltas for females group;
- \( \sigma_{xy} \): The correlation between males and females’ deltas.

The Perpendicular distance that each point deviates from the major axis was calculated from the formula:

\[
D_i = \frac{AX_i - Y_i + B}{\sqrt{A^2 + 1}}
\]

Where:

- \( X_i \): Represents males’ delta value for item \( i \);
- \( Y_i \): Represents females delta value for item \( i \). \((D_i)\)

Those items with \((D_i)\) values in excess of one standard deviation reveal DIF (Osterlind, 1983). In this study,
the larger \((D_i)\) is, the more biased the item. A signed transformed difficulty measure of DIF, which preserved both
the direction and magnitude of DIF, was obtained by attaching a positive sign to \((D_i)\) if the item reveals DIF in
favor of females and a negative sign if the item reveals DIF in favor of males (Abedalazeez, 2010).

**Results and Discussion**

Table 1 shows the summary results of the LR method to identify DIF on the mathematical ability scale for
each of 30 items. Seventeen items or 43% of the items revealed DIF (i.e., the items 1, 5, 8, 21, 22, 23, 24 and 26
were revealed uniform DIF, whereas the items 9, 10, 11, 13, 16, 27, 28 and 40 were revealed non-uniform DIF).
The items 1, 8, 10, 13, 16, 21, 24, 26, 28 and 40 were in favor of males, whereas the items 5, 9, 11, 22, 23 and
27 were in favor of females.
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**Summary Result of the LR Analysis**

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Table 2 shows the DIF statistic of the TID method for each of 40 items. The TID method flagged ten items at the significance level of 0.05 (the item 27 was in favor of female students, whereas the items 1, 14, 19, 20, 25, 33, 34, 37 and 39 were in favor of male students).

Table 3 summarizes the consistency in which the TID and LR methods flagged the items. The two methods were agreeable in allocating 14 items as revealing DIF, and ten items as not revealing DIF. As such, the percentage of agreement between TID and LR methods is 45% (i.e., $16 + 2/40 = 45\%$).

### Discussion and Conclusions

In summary, the percentages of agreement among the two approaches in detecting DIF are relatively low. Not surprisingly, simulation studies from educational testing experts have found that LR-based DIF detection techniques enable the detection of both uniform and non-uniform DIF, whereas TID DIF detection techniques unable the detection of both non-uniform DIF.

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</table>

Notes: * The item reveal DIF; $P_d$ item difficulty for males; $P_f$ item difficulty for females; $\Delta M$ delta value for males group; $\Delta F$ delta value for females group; $Z_d$ z score for males; $Z_f$ z score for females.
Table 3

<table>
<thead>
<tr>
<th>Results from TID</th>
<th>No. of non-flagged items</th>
<th>No. of flagged items</th>
<th>Marginal total</th>
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<td>Marginal total</td>
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</table>

The theoretical reasons for the lack agreement between both methods in the identification of DIF of items are given by Hunter (1975) who discussed several factors which may cause an item to be labeled as revealed DIF when, in fact, no DIF exists. These are: (1) non-unidimensional tests; (2) differences in ability distribution of the two groups; (3) differences in item quality; (4) guessing; and (5) nonlinearity of regression. Finally, one should consider the fairness of an item in addition to its statistical index of bias. Also, this result helps to explain the low and moderate agreement reported in the measurement literature among DIF methods concerning items flagged as reveal DIF. The fact is that studies of convergence of methods for investigating DIF are influenced greatly by the unreliability of the statistics (Abedalaziz, 2010).

The DIF analysis pointed to the conclusion that females had an advantage over males on the numerical ability, whereas males had an advantage over females on items involving spatial ability and deductive ability. The tendency for males to perform better than females on spatial ability and inductive ability and women to perform better on numerical ability is consistent with previous findings (Willson, Fernandez, & Hadaway, 1993; Gallagher, DeLisi, Holst, McGillicuddy-DeLisi, Morely, & Cahalan, 2000).

In previous studies, however, females usually performed better on number and computation. The fact that this test was tied to a specific curriculum did not appear to help females’ performance. The researchers consistently found that male students are superior in geometry and visualization (Geary, 1996). On the other hand, females show superiority in computation based on the data available. Gender differences in achievement of mathematics in favor of boys have been found in standardized tests and are most prominent at the very high levels of achievement (Leder, 1992). These differences are likely to both content and ability dependent. While males outperform females in scientific and mathematical tasks, females outperform males in tasks involving verbal abilities.

There are many studies that focus on differences between men and women in tests (Gallagle et al., 2000; Kimball, 1994; Willingham & Cole, 1997). From the findings of earlier studies, one conclusion that can be drawn is that men have a better spatial ability than women (Geary, 1996). Men use this spatial more often than women when solving problems, which can give advantages while solving certain kinds of problems in geometry (Geary, 1996). Many studies indicated that women are better than men in verbal skills, which can give them advantages on items where communication is important. Women also score relatively higher on tests in mathematics that better match coursework. Men tend to outperform women in geometry and arithmetic and algebraic reasoning questions. Women tend to be better at intermediate algebra and arithmetic and algebraic operations (Willingham & Cole, 1997). Gallagher et al. (2000) found men outperformed women in all kind of problems, but that the differences were greater for problems requiring spatial skills or multiple solution paths than for problems requiring verbal skills or containing classroom-based content.

Spatial abilities were reported to have relationship with mathematics test scores (Casey, Nuttall, Pezaris, & Benbow, 1995; Geary, Saults, Liu, & Hoard, 2000; Nuttall, Casey, & Pezaris, 2005). This relationship indicates
that gender differences in spatial abilities may contribute to gender differences in mathematical problem-solving.

The study provides evidence that there are gender differences in performance on test items in mathematics that vary according to content even when content is closely tied to curriculum. The presence of a gender related DIF in mathematical ability test can be attributed to: (1) the unfamiliar with the content of the items which caused the examinees to be attracted to the incorrect options; (2) the ambiguities in the item stem, keyed response, or distracter; (3) the disparities in the matched examinees’ exposure to concepts or skills reflected on the items; and (4) the inability of the matched examinees to understand the concepts reflected on the items (Pedrajita, 2009).

References


DETECTING A GENDER RELATED DIF


