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Zimbabwean female participation in physics: The influence of identity formation on perception and participation

Anna Gudyanga[1]* and Raj Kurup[2]

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*Corresponding author: Anna Gudyanga, Department of Educational Foundations Management and Curriculum Studies, Midlands State University, Gweru, Zimbabwe
E-mails: gudyangaa@gmail.com, gudyangaa@msu.ac.zw

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Additional information is available at the end of the article

Abstract: The study investigated the influence of identity formation on the perceptions and participation of Zimbabwean Advanced Level (A' Level) female adolescent students in physics. Nine female adolescent students eighteen years and above: three doing mathematics and physics, one doing physics without mathematics and five doing mathematics without physics were purposively selected. The data generating instruments used were semi-structured interview and classroom observation guides as well as document analysis. Findings show that female students associate scientists within a masculine framework in a Eurocentric environment, specifically those scientists who are depicted in their textbooks. The female students doing physics had a positive physics identity which resulted in the formation of positive perceptions towards physics and their participation in the subject. The female students with a negative physics identity perceived physics, to be irrelevant to their future aspirations, difficult, too involving and masculine causing them not to opt for physics as one of their A' Level subjects. Thus, the formation of a positive or negative physics identity by female adolescent students influences their positive or negative perceptions of physics and hence their participation or non-participation in the subject, respectively. We recommend that a wider and more comprehensive study nationally is warranted to confirm the findings of this study.

Anna Gudyanga

ABOUT THE AUTHORS

Anna Gudyanga's research interests include Gender Issues, HIV/AIDS Education, Curriculum Issues in Science Education, Education and Transformation, Socialization in Children, Identity Formation and Adolescent Development

Raj Kurup's area of research focuses on Science Education, with special focus on Teachers' Perceptions in the Nature of Science.

PUBLIC INTEREST STATEMENT

Education an effective tool for development especially of females because it raises economic productivity, lowers infant and maternal mortality. Female students are under-represented in science when Zimbabwe needs more scientists to meet its developmental agenda in a technological world. More so, science in general, plays an influential role in the life of an individual and the development of a nation in that it provides the basis for an innovative and globally competitive workforce. Due to its relevance to technology and infrastructure, physics tends to limit advances in many areas of scientific study. Fewer females in an already limited pool of human capital compounds the adverse effect of decreased physics enrolment can have on society. Thus, there is need to explore the influence of identity formation on perception (from female students themselves) and how this in turn influences participation of female students in physics.

Subjects: Quantitative Methods; Perception; Gender Issues; Education Studies

Keywords: identity formation; physics identity; negative and positive perception; physics and participation

1. Introduction

The decline in numbers of students enrolling to do physics is not unique to Zimbabwe alone but it is a worldwide phenomenon. Numerous studies (Angell, Guttersrud, Henriksen, & Isnes, 2004; Lyons, 2006; Owen, Dickson, Stanisstreet, & Boyes, 2008), have shown that women are greatly under-represented in the field of physics in a number of countries. There is a low participation of female students in physics in Zimbabwe when 52% of the population are women (National Gender Policy, 2013). For example, in 2011, the national statistics showed that 15.98% of the students who were doing physics were female (Zimbabwe Schools Examination Statistics, 2011). In Gweru district, only 25% of the students who were doing physics were girls (Gweru District Schools Statistics, 2013). More so, to educate a female is to educate a whole family and what is true of families is also true of communities and ultimately the whole country thus allowing females greater control of their lives (UNICEF, 2000). Although a large number of Western studies (Coyle, 2006; Murphy & Whitelegg, 2006; Olorode, 2005) have reported on the reasons for low uptake of physics by the girls, very few studies have been carried out in developing countries where cultural and gender role patterns are distinct, widespread and unescapable. Furthermore, the influence of identity formation on perceptions of and participation of female students in physics in Zimbabwe has received little attention. More so, science in general plays an influential function in the life of an individual as well as in the development of a nation in that it provides the basis for an innovative and globally competitive workforce. Physics is a required subject to pursue careers in the field of medicine, engineering and other areas.

Table 1 indicates that the number of female students who decided to do physics in year 2014, at school level is far less than the number of males. The same table indicates that at district level in 2012 and 2013 the number of female students who chose to do physics was also less than males. The same trend is shown at national level in year 2011. The situation is worst in rural schools where the lack of facilities (like laboratories) prevent schools from offering physics. Table 1 shows some important physics statistics by gender. In all the four participant schools (low and high density, rural and all-girls) shown in the table, physics was not being taught at the rural school, therefore mathematics was considered for the rural school. It is evident from the table that males dominate in all sectors and are the teachers in senior science classrooms in Zimbabwe. Not much change is seen despite the adoption of a National Gender Policy in Zimbabwe since 2004.

Table 1. Number of students doing physics and their teachers by gender in 2014

School/district/nation	Students		Teachers	
	Female	Male	Female	Male
Low density school[1]	10	56	0	2
High density school[2]	2	36	0	2
Rural school[3]	2	12	0	2
All-girls school	50	None	0	1
Gweru District Schools Statistics (2012)	35	94		
Gweru District Schools Statistics (2013)	40	119		
National Statistics (2011)	187	1,170		

Sources: Zimbabwe Schools' Education Council (ZimSEC) (2011) and Gweru district' schools' statistics (2012, 2013).

[1]Middle income.

[2]Low income.

[3]Impoverished.

Hence, it is clear that simply constituting relevant policy is not enough to ensure participation. A consideration of the influence of identity formation on perception of and participation in physics, through sociocultural lenses is vital if female participation is to be increased in the sphere of the physical sciences. This study fills the gap described above in that it focuses on the influence of identity formation on female students' perception of and participation in physics in a developing education system like that of Zimbabwe.

2. Rationale and research questions

Education in general is an effective tool for development especially of females because it raises economic productivity, lowers infant and maternal mortality, improves nutrition and promotes health including helping to prevent the spread of HIV/AIDS (UNICEF, 2000). Female students are under-represented in science when Zimbabwe needs more scientists to meet its developmental agenda in a technological world. More so, science in general, plays an influential role in the life of an individual and the development of a nation in that it provides the basis for an innovative and globally competitive workforce. Zohar and Bronshtein (2005, p. 62) explore the "effect of small female enrolment in physics" and they point out that fewer female physics students adds to the problem of fewer physics students in general. When females choose not to study physics in high school, it leaves smaller numbers of students that are available to become scientific professionals. Due to its relevance to technology and infrastructure, physics tends to limit advances in many areas of scientific study. Fewer females in an already limited pool of human capital compounds the adverse effect of decreased physics enrolment can have on society. Thus, there is need to explore the influence of identity formation on perception (from female students themselves) and how this in turn influences participation of female students in physics. The research questions guiding this study were framed as:

(1) What are the perceptions of the Zimbabwean female students towards physics?

(2) What is the influence of identity formation on perception of and participation in physics?

While an attempt is made to address these questions from the perspective of female adolescent students, a brief overview of the concept "identity" in relation to gender schematic theory (GST) and the theoretical lens through which this study is situated follows as a point of departure.

3. Identity and gender schematic theory

According to Siebers (2004, p. 76), the concept of identity has "a solid scientific foundation" that has been developed from several theoretical debates. Castells (2004, p. 6) defines *identity* as, "people's source of meaning and experience," while Polman and Miller (2010, p. 884), consider it to be "the story that we each create for ourselves." Identity is also personal and the "manner in which we live is shaped by our sense of who we are" (Shi & Babrow, 2007, p. 316). Our personal sense of who we are and our source of meaning (identity) which influences the way we live, is shaped by our communities (Wenger, 2000). Identity is formed (and informed) by gender, it is shaped by context and it bears a direct relationship to the choices we make. These choices depend on how we see ourselves and how inclusive those choices make us feel within our contexts.

Socialisation links the individual to a collective life by moulding members into compliance and cooperation with social requirements. Who one is and who one desires to be at any given moment is always under negotiation and is contingent upon the social, cultural and historical context in which one seeks to author oneself with and against the expectations of others (Wortham, 2006). How students engage in school science is influenced by how students view themselves and whether they see themselves as the kind of person who engages in science. It is therefore crucial to understand students' identities and how they interact with school science identities (Brickhouse, Lowery, & Schultz, 2000).

Individuals within a culture may differ from one another in the degree to which they utilise cultural definitions of masculinity and femininity as standards against which they perceive, categorise and evaluate gender-related information (Franklin, 2012). The one reason why boys and girls learn to behave differently is because they are treated differently by their parents and the communities. Our socialisation into gender appropriate roles begins when our sex is identified[1] (Franklin, 2012, p. 5). Gender is probably one of the very first influences on identity, hence the need to explain the GST. GST theory portrays the child as both actively constructing gender categories and responding to environmental cues. It is based on the idea that children form organised knowledge structures (*schemas*[2]), which are gender-related conceptions of themselves and others. These *schemas* influence children's thinking and behaviour (Martin & Ruble, 2004). GST proposes that a basic understanding of gender is all that is required to motivate children's behaviour and thinking. The child, in short, learns to encode and to organise information in terms of an evolving gender *schema*, i.e. a network of associations that organises and guides an individual's perception (Bem, 1983; Franklin, 2012, p. 100). GST thus construes *perception* as a constructive process in which the interaction between incoming information and an individual's pre-existing schema determines what is perceived. Once these gender *schemas* have become internalised, the child begins to use these as a marker for their own behaviour. Bem (1983, p. 605) concludes that:

> The gender schema becomes a prescriptive standard or a guide and self-esteem becomes its hostage. Here, then enters an internalised motivational factor that prompts an individual to regulate his or her behaviour to that which conforms to the cultural definition of *femaleness* and *maleness.*

As alluded to in the paragraph above, an understanding of gender is required to positively motivate female students' behaviour and thinking in as far as science is concerned. A view of science as a "culturally-mediated way of thinking and knowing suggests that learning in science can be viewed as engagement with scientific practices" (Wenger, 1998). Learning science on the one hand has been viewed as a process of acquiring an understanding of the culture of science and applying these understandings in new situations (Brickhouse et al., 2000). On the other hand, learning in general is viewed as an apprenticeship, where students forge identities in communities of practice. Lave (1992, p. 3) explains:

> Learning is a process of coming to be, of forging identities in activity in the world. In short, learners are never only that, but are becoming certain sorts of subjects with certain ways of participating in the world … Subjects occupy different locations, and have different interests, reasons and understandings of who they are and what they are up to.

In developing a deeper knowledge base as a lens through which to answer the main research questions, a suitable theoretical perspective was deemed essential for the purposes of this study.

4. Theoretical perspective

Wenger's (1998) social theory of learning (STL) and in particular the notion of learning in communities of practice was used to frame the study theoretically. Wenger's (1998) STL is premised on the fact that learning is a social enterprise and that learning within communities of practices "shape not only what we do but also who we are and how we interpret what we do" and construct identities in relation to these communities (Wenger, 1998, p. 4). We used Wenger's (1998) community of practice (CoP) model as an organising framework to understand the influence of identity formation on perception of and participation in physics. A CoP is a social group with a shared history, mutually engaged in a practice on an ongoing basis to advance the goals of some shared enterprise (Wenger, 1998). Such communities are both defined and cohered by three characteristics: "the existence of a joint enterprise (something to do), mutual engagement (others to do it with), and a shared repertoire (physical, social, communicative, and historical resources with which to act in doing it)" (Zohar & Bronshtein, 2005, p. 319). Individuals participating in such communities each have an identity i.e. the way we perceive ourselves. In Wenger's (1998) work, CoPs are informal naturally occurring, spontaneously evolving groups. It is important to note that an individual's sense of community develops out of mutual engagement (participation) in the CoP's joint activity (Wenger, 1998). This social theory posits that individual learning is the development of modes of participating with others in society.

For Wenger, identity is, in the biggest sense, the "who we are" that develops in our own minds and in the minds of others as we interact with them. It includes our knowledge and experiences, but also our perceptions of ourselves (i.e. our values, beliefs, desires, motivations and self-identifications), others' perceptions of us, and our perceptions of others' perceptions of us that develop as we participate in communities with one another. As such, our identities do not exist only within ourselves, but rather are strung between us and the others with whom we interact. In a sense, then, our identities are the vehicles from within which we participate with others in a community. They are "vehicles that provide both potentials for and limitations to our participation, and that are modified as we learn and grow through mutual participation in joint enterprises with others" (Van Zoest & Bohl, 2008, p. 320).

As individuals interact within communities, they attempt to make meaning out of what they are doing (that is, they both try to understand their actions and make them meaningful). This meaning making is done through the interaction of participation and reification. Wenger lists three modes of participation through which individuals interact with others: (a) engaging mutually with others in activity (doing things together or with others in mind); (b) understanding and fine-tuning the tasks at hand; and (c) developing a shared repertoire of resources, discourses and styles for working on the tasks.

Reifications are the products (conceptual and physical) of doing things, and are also inputs to the processes of doing more things, i.e. inputs to further participation. Reifications are important for two reasons. First, they are a key for continued meaning making and productivity within a given community. As such, they provide participants-shared resources around which to focus their efforts. Second, reifications are a key means by which different communities interact with each other, since they are the parts of a community that are most transportable to other communities.

CoPs are limited by their size and scope, which are marked by boundaries. Boundaries determine the various levels of participation available to individuals and the modes of participation that are considered feasible. That is, boundaries help define the extent to which an individual is considered a participant in a community, as well as the ways in which individuals participate and make sense of what they are doing. Conversely, by their very participation in the enterprise and their efforts to make sense of (and take meaning from) it, individuals themselves negotiate and redefine what is to be done and how it will be done with others. They in effect, then, negotiate the form of the community itself and thus, its boundaries. Because people participate from "within" their identities, which are in turn shaped by modes of participation within communities, individuals' identities both form, and are formed by, this process of boundary negotiation (Van Zoest & Bohl, 2008, p. 320).

A person's own, and others', perceptions of his/her location and trajectory within a community are key aspects of that person's identity in practice. That is, a person's level and modes of participation might be very different if his/her identity within a community were peripheral and marginal, rather than being peripheral and inbound (ibid. p. 321). Within Wenger's perspective, learning is taken to be the same thing as the development of one's identity in community. As one learns (either within or outside of a community), one develops new ways of participating with, and within, communities (Van Zoest & Bohl, 2008, p. 322).

5. Research methodology

A qualitative research methodology was used for the purposes of this study. Qualitative data provide a greater depth of information that present a full picture of the influence of identity formation on perception and how this in turn affects the participation of female students in Advanced Level physics. We situated this study within the interpretive paradigm which involved collecting the stories of

Table 2. School category and participants' subject choices

School context	No of student	Subjects
Low density urban schools	S1	Mathematics and Physics
• Educated community • Middle income of above $400 • Well resourced • Five laboratories (three for seniors and two for juniors)	S4	Mathematics only
High density urban schools	S2	Mathematics and Physics
	S3	Physics without Mathematics
• Low income (between $201–$400) • Most people not educated • Not well resourced • Two laboratories only (one for seniors and one for juniors)	S5	Mathematics only
Rural school	S6	Mathematics only
• Impoverished below $200 • Uneducated community • Poorly resourced • No laboratories	S7	Mathematics only
All-girls urban school	S8	Mathematics and Physics
• Educated community • Well resourced • Six laboratories (three for seniors and three for juniors)	S9	Mathematics only

lived experiences (Creswell & Maietta, 2002). An interpretive paradigm assumes that people's actions are meaningful and that these meanings have to be interpreted in the context in which they take place (McNeill & Chapman, 2005). The phenomenon of identity construction in this study is therefore, understood through the eyes of the participants and their subjective views.

5.1. Sample and context

The Zimbabwean Government, through the Education Act of 2004, made it clear that schools fall into two broad categories as outlined below.

Schools in Zimbabwe are classified:

- as either government schools or non-government schools; and
- in such other categories as the Minister may determine, taking into account the social and economic standards of the communities in which the schools concerned are situated (Education Act, 2004, p. 621).

For the purpose of this study, nine participants were purposively sampled from the two broad categories and invited to participate. The four schools selected for this study from the two broad categories could further be classified based on the contexts of the schools. These schools were stratified first into three categories, namely, rural (impoverished), high density urban (low income), low density urban schools (middle income) and low density all-girls school (also middle income). One school each representing each of the categories was purposively selected for this study. Three were co-education government schools categorised as rural, low and high density (taking into account the social and economic standards of the communities in which the schools are situated) and one was an all-girls non-government school categorised as low density. Low density schools are situated in an educated community of middle income (above $400–$999) earners. Generally, these schools are well resourced with adequate laboratory facilities (usually three laboratories for senior and two for junior students) and well-qualified science teachers. The all-girls school was a low density school as well with six laboratories, three for junior and three for senior students. Generally, high density schools are not well resourced having only two laboratories one for the senior and one for the junior students. Most people in the community where high density schools are located are not usually formally educated and can be categorised as low income (between $201 and $400) earners. Rural schools are poorly resourced with no laboratories. The impoverished community is not formally educated and living on less than $200 per month.

Table 2 provides an overview of the context of the schools and the subject choices made by the participants who were purposively selected for this study. Purposive sampling entails that the inquirer selects individuals and sites for a study because they can suitably inform an understanding of the research problem and the central phenomenon being studied (Creswell, 2007, 2013).

As can be seen from Table 2, S1, S2 and S8 enrolled for both physics and mathematics, while S3 was enrolled for physics only. S3 is an anomaly as students are generally not allowed to study physics without mathematics. The other five students (S4, S5, S6, S7 and S9) had all enrolled for mathematics only. Female students who enrolled for mathematics only were included in this study as they had the potential to study physics as well at A-level. Furthermore, it was considered that their narratives could provide insights into the reasons why they (as females) did not choose to do physics.

5.2. Research instruments

A multimodal method of generating data was employed in order to obtain data from the female participants in this study. They included: semi-structured Interviews (generating narratives/stories); document analysis and classroom observations where by the researchers observed female students learning their theory and practical lessons in physics. The use of multiple sources of data assisted in addressing a broad range of historical, attitudinal, perceptual, behaviour and process issues, contributing to trustworthiness of the data in that it provided a means of confirming or cross checking the accuracy of emerging findings which contribute to the validity in this study. Hence, this triangulation is a validity procedure where we searched for convergence among different sources of information to generate themes or categories in a study (Creswell & Miller, 2010). The semi-structured interviews in this study could be referred to as narrative interviews. While an interview is a face-to-face verbal interchange, in which the interviewer attempts to elicit information from another person or persons (Jennings, 2005), a narrative on the other hand is an in-depth type of interview where participants respond to fewer and less-structured interview questions (Connelly & Clandinin, 2006). Narrative is a part of how people understand the world they live in and it serves as a way of communicating that understanding to others (Connelly & Clandinin, 2006).

The interviews began with the researcher having a conversation with each participant who was stimulated to tell their narratives to answer broad open-ended questions. The validity of the stories hinged on the assurance that the female students had the same understanding of identity formation as defined by the literature (see above). All of the instruments were therefore, pilot tested in high schools which were not a part of the schools selected for the study, but believed to share similar characteristics. While interview questions were refined based on the pilot study, the concepts were also made explicit at the start of the interviews so that a similar understanding of these concepts was the premise for their stories. The narrative interviews were transcribed and coded according to emerging themes in an attempt to make meaning of the data. Female students were observed learning their theory and practical lessons in the laboratory. To minimise the hawthorn effect, four lessons were observed before recording the data. The documents showing the enrolment of students doing physics by gender were analysed. Participants were given the transcriptions and asked to comment on their accuracy. Relevant changes were made based on participants' comments on the final narrative. In this way, the participants added credibility to the qualitative study by having a chance to react to both the data and the final narrative (Creswell & Miller, 2010). The documents showing the enrolment of students doing physics by gender were analysed.

Ethical clearance from our institution was obtained to carry out the study. We were also cleared by the Ministry of Primary and Secondary Education this allowed us to visit the sampled schools. We were also given clearance by the heads of schools to interview their female students doing mathematics and physics and only mathematics. The participating students consented in writing to engage in interviews and class observations. Anonymity and confidentiality were upheld throughout the study. The purpose of the study was openly and honestly explained in a simple enough manner to all participants. We also made clear how the information from interviews and class observations were going to be used. The female participants were told that they could freely and easily withdraw from the study at any time if they so wished.

6. Analysis of results and discussion

The labelling of a child as male or female, soon after birth begins the socialisation process. This process places the child within a particular community into either a masculine or feminine practice (Paechter, 2003). They are immediately treated according to the ways that are legitimate for members of that community; this in turn develops into a personal trajectory of relationship with the members in the community of practice (Lave & Wenger, 1991). In response to this naming and positioning, other members of these communities, or of other related communities, expect and encourage particular forms of behaviour from that child (Paechter, 2003). The section below considers the perceptions of Zimbabwean female students towards physics.

6.1. The perceptions of the Zimbabwean female students towards physics

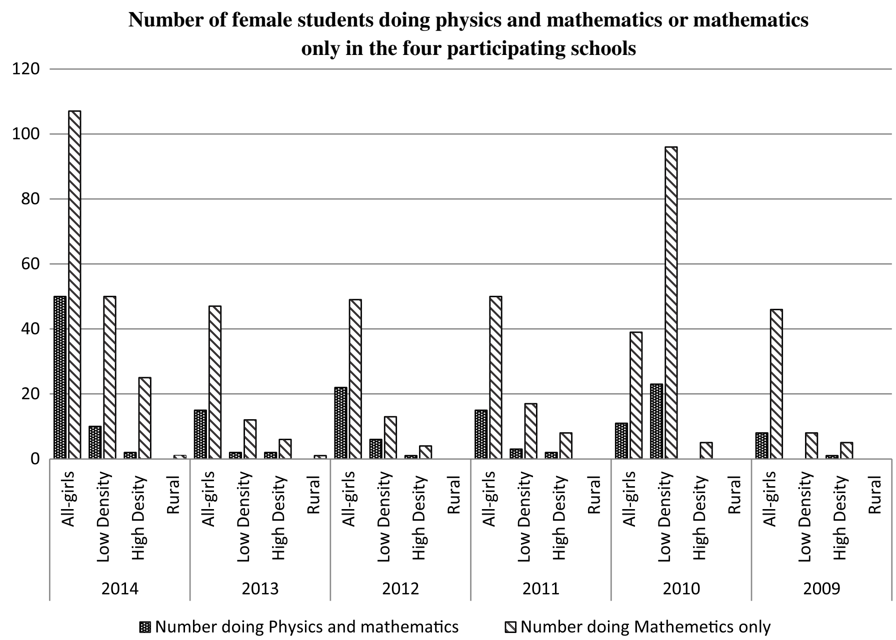
Traditionally, students at A-level enrol for both physics and mathematics as a combination of subjects to pursue a career in physics or in engineering. However, an analysis of female students' enrolments at A-level in these two subjects in Zimbabwe indicates a different picture in the sense that more female students register for only mathematics (except the rural school which has very low numbers) and seem to avoid taking the combination of physics and mathematics as subjects of choice. Data from document analysis (see Figure 1) show the number of female students doing either physics and mathematics or only mathematics at A-level in the four participating schools from 2009 to 2014. These enrolment figures of the female students participating in this study over the past six years indicate certain trends.

Firstly, there are far more female students doing only mathematics compared to those doing physics, and this distinction is particularly prominent in 2010 and 2014. The reason could be that Zimbabwe introduced the use of multi-currency halfway through the year 2009 as a way of lowering high inflation. Before 2009, a large number of parents could not send their children to schools because of the financial turmoil in the country. Since the introduction of the United States Dollar as a viable currency in Zimbabwe, considerable number of families started returning from the diaspora which resulted in large numbers of students who had previously dropped out of school re-entering the school system. This gave rise to the increased student numbers at A-level in 2010.

Secondly, the total number of females doing either mathematics only or physics and mathematics appear to be greater in the all-girls school compared to the other three categories of schools. This is mainly because this school is well resourced with science laboratory facilities and quality teachers which tend to attract more students into the maths and science stream at the school. In addition, being an all-girls school, the female students are not exposed to negative perceptions towards them in doing maths and physics from male students as is the case in the co-education schools.

Thirdly, the number of female students registered for these two subjects is relatively low in the high density and rural schools compared to the other types of schools. The high density school is under-resourced in terms of laboratory facilities, materials and equipment. There is a high teacher

Figure 1. Female students doing physics and maths in the four schools.



turnover as these schools cannot retain experienced teachers who seek employment in institutions giving school-based incentives.

Lastly, the rural school does not offer physics because it does not have well-equipped science laboratory facilities. It is interesting to note that at this rural school, from 2009 to 2014, only two female students enrolled to do mathematics i.e. one in 2014 and another one in 2013 and none in 2009 to 2012 as shown in Figure 1. This may be due to the fact that the rural school is considerably under-resourced with poor teacher capacity and, hence, the female students are not well nurtured. Female students may find it more difficult to go against deeply rooted cultural perception that females are not capable enough to do mathematics, and this results in fewer female students opting to study mathematics. The cultural view that mathematics is not a suitable subject to be studied by female students seems to be stronger in the school located in the rural community compared to other school categories. During the interviews, the participants stated that female students were discouraged from studying mathematics by the community. This is an indication that only the strong-willed would be courageous enough to opt to study mathematics in a rural school.

Table 3 summaries data that were obtained from the semi- structured interviews that were carried out with the female participants who described their perceptions towards physics.

As shown in Table 3, all nine female participants in this study perceived physics as a masculine subject. This may be due the socialisation they experienced from birth that physics is culturally stereotyped as being masculine and thus not a suitable subject to be studied by females, but is suitable for male students only. Many scholars of gender issues (Kelly, 1985; Rosser, 1989) have claimed that the inherent masculinity of science is the prime reason for female students' avoidance of science. In this context, it is interesting to note that physics is taught by only male teachers in all the participating schools. This is very pertinent in that the female participants do not have female role models to function as inspirational examples to help them realise that females are able to overcome traditional gender barriers and achieve high levels of success in physics (Lockwood, 2006).

The students doing only mathematics largely have the potential to study physics as well but they do not. An analysis of female students in the four participating schools indicates three distinct categories of students based on their subject choices and are summarised in Table 3.

Table 3. Female Students' perceptions towards physics

S1	S2	S8	S3	S4	S5	S6	S7	S9
Doing physics and maths	**Doing physics and maths**	**Doing physics and maths**	**Doing physics without maths**	**Doing maths only**	**Doing maths only**	**Doing maths only**	**Doing maths only**	**Doing maths only**
Female students' perceptions of physics								
Masculine	Masculine	Masculine	Masculine	Masculine	Masculine	Masculine	Masculine	Masculine
It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers	It's taught by male teachers
It's hard	A bit hard	It's hard	It's kind of hard	A very difficult	Very hard	Must be very interesting	Must be very interesting	It's interesting
Challenging	Challenging	Challenging	Challenging	Complicated and abstract	It's complex and abstract	Perceived as hard	I am told it is hard	Irrelevant to my career aspirations
Too involving	Too involving	Demanding and requires logic	Requires a lot of concentration	Very boring	Physics is very boring			It's Challenging
Very interesting	Very interesting	Very interesting	Very interesting	Have negative perception of physics	Have negative perceptions of physics			
It's very important	Physics is very important	It's very important	Very important	Lacked female role models	No female role models,			
Very relevant to daily life	Physics is practical to daily life	Very practical	Applicable to daily life	Irrelevant to my career aspirations	Irrelevant to my career choice			
Am to work harder	Has to work hard	Working very hard	Physics is the love of my life and hence I am working hard					

The first category relates to students doing physics as one of their subjects. These female students perceive physics as:

> A hard/challenging; too involving or demanding; requiring logical reasoning; but very interesting; very important and can practically be applied to daily life.

Despite the fact that these students perceived physics as a challenging subject, they liked the challenge and were determined to work hard to show that they could match the performance of their male counterparts in the subject. An additional motivating factor could have been that their male physics teachers always reminded them to work harder since they perceived them as less intelligent compared to the male students.

The female students' perceptions of physics as *interesting*, *important* and *very relevant to daily life* is an indication that they had developed positive perceptions of the subject which might have influenced them to study physics. S1 and S8 claimed that they liked challenges indicating that they had formed positive physics perception and thus opted to do physics. S2 wanted to prove that girls can also do physics and was excited to be in this male domain. S1, S2, S3 and S8's positive perceptions towards physics resulted in their participation in physics. They were comfortable in handling laboratory equipment when they were observed carrying out practical experiments in pairs. It is, therefore, a positive identity formation which might have influenced the female students' positive perceptions towards physics and thus their active participation in the subject.

Lave and Wenger (1991) and Wenger (1998) argue that learning involves an interaction between experience and competence. The female students (S1, S2, S3 and S8) doing physics saw themselves and identified themselves as "confident," "determined," "fearless," "bold," "intelligent" and "...up to proving a point." It was clear that they were stronger personalities who could steer away from culture and peer pressure. They were more assertive about what they wanted to do in life. Their positive identity or their sense of who they are influenced their social perception of physics as a subject and their perception of physics in turn also caused them to participate in the subject.

S4 and S5 form the second category of students who chose to do only mathematics and not physics, despite the fact that the schools they were at offered physics as a subject at A-level. These female students had negative physics perceptions towards the subject. They chose to do only mathematics at A' Level, while those with positive perceptions of physics displayed enthusiasm and commitment to achieve high levels of performance in the subject. The female students doing only mathematics considered physics to be very difficult and thus felt uncomfortable to be amongst boys since they considered physics to be in the male domain. They feared to fail this subject which they perceived to be very hard. Their perceptions of physics as being very *hard, abstract, complicated and very boring* could have been key factors which inhibited them from choosing this subject. In addition, the two students highlighted the lack of female physics teachers as role models as another reason to opt out of physics. Their negative perceptions in relation to physics resulted in them choosing a career path where physics was irrelevant.

The third category of students (S6, S7 and S9) chose only mathematics for different reasons. S6 and S7 (studying at a rural school) lacked the opportunity to study physics because their parents could not afford to send them to schools that were offering physics. This resulted in these female students studying mathematics without physics. These two female participants found the subject to be interesting based on their O-level experience and were actually disappointed to note that physics was not being offered at this rural school as it was a requirement to their career aspirations. S9 was at a well-resourced school and had the potential and opportunity to do physics. Although she was interested in physics, she chose only mathematics because her career ambition to be an economist did not require physics as a subject at A-level.

The findings of this study are not in any way peculiar to Zimbabwe. Other researchers (Angell et al., 2004; Checkley, 2010; Lyons, 2006) produced similar results in that physics is perceived as interesting, but difficult and work-intensive or boring and uninteresting. This intimidating reputation of physics (that it is a difficult subject) may be creating a barrier for bright minds to participate in the subject. Further, Angell et al. (2004) claimed that the perception of physics as being difficult tends to result in the development of a general negative attitude towards the subject. However, the female participants studying physics who perceived it as interesting were motivated to pursue careers in the fields of physics and engineering. This was reflected in their active participation in laboratory work as well as a leading role they assumed in giving presentations to the whole class on different topics in physics.

In summary, female students who hold negative perceptions towards physics chose to do only mathematics at A' Level, while those with positive perceptions of physics displayed enthusiasm and commitment to achieve high levels of performance in the subject. The female students having positive perceptions actively participated in their physics community of practice. It is therefore, evident that the female students' identity formation influenced their perception of physics (that it is masculine and difficult). This in turn caused them not to participate in their large numbers in physics (a community of practice). Having looked at the female students' perceptions of physics, the next section considers the participation of female students in physics.

6.2. Female students' participation in physics

The data gathered from classroom observation indicate that the A-level physics classrooms/laboratory environments of female students doing physics were conducive for learning in a CoP. This is because female students were encouraged to ask questions, read more, take apparatus first before distributing to male students and the male students were asked to share when there is a shortage of equipment. They were also urged to work harder and this, in a way may have aided these female students to construct a positive physics identity.

During classroom observation, when students were being taught one theory lesson and one practical work, we observed that the teachers had more or less same interaction time with both male and female students. They treated the male and female students equally well without showing any favouritism.

All the students were asked to find information on given topics so that they could come to present to the whole class. There was good rapport between the female students doing physics and their teachers. There was teacher–student as well as student–student interaction in this physics community. The teachers were asking thought-provoking high order questions. What must be known is that physics is a social construct which is informed by students' lived experiences and social interaction. As students develop knowledge and competence and meaning from these interactions, they begin to construct their identities in terms of who they wish to be in relation to their communities. Hence, one's self-concept shapes one's attitude to physics and is a predictor of students' decisions to continue to study physics.

The female participants doing physics (S1, S2, S3 and S8) were observed during the practical and theory lessons by way of the interaction between these students and their teachers are worth noting. For example, the male physics teacher of S1 reprimanded male students for laughing at female students during lessons. S1 always took a seat in front of the class and during the theory lesson she remained in the laboratory to ask the teacher pertinent questions. She was competing well with male students in terms of tests. This female student was comfortable in handling apparatus and was also very comfortable both in the laboratory and in the classroom. She actively participated in both theory and practical experiments. S1 voluntarily paired with a male student and not with the other female student as they were doing the practical experiment in pairs demonstrating shared practice in a CoP. They were investigating how the motion of a pendulum bob is affected by the height above the bench. She was actually doing the experiment and the male partner was recording the time the bob took for each complete swing. There was an enabling classroom environment with respect to resources and promoting learning in CoP. S1's voluntary pairing with a male student may indicate that the rapport between the two students was good and that she was confident and courageously creating an identity for herself.

S2 was competing well with male students in terms of tests and class exercises. As was the case with S1, she also paired with a male student and not with the other female student during the practical work. S2 had stated during interviews that she was excited to be in a male-dominated classroom. This may suggest that she was interacting well with the male students and that she was determined and confidently creating a physics identity for herself as well. They were investigating the extension of springs supporting a load as the load was varied. They ended by drawing a graph individually as was required in presenting the data collected during the experimental activity. The whole group was working well. All the students were able to complete their task within the given time. During the theory lesson, S2 made a presentation to the whole group on electromagnetic induction demonstrating understanding and meaning making. She was very confident in explaining to the whole class the factors that affect electromagnetic induction. It shows that the opportunities and support provided by the male physics teachers of S1 and S2 resulted in these female students gaining confidence and taking a leadership role to become active participants in the learning community.

S3 always took a seat in front of the class. She was comfortable handling the apparatus when they were carrying out the experiments in the laboratory. Because the teacher had requested that they work in pairs showing shared practice in a CoP. S3 had no option but to pair with a male student since she was the only female in that class. These were the male students who were subjecting her to immense peer pressure. S3 used to ask questions but of late she was no longer comfortable asking questions during lessons. This was because of the behaviour of male students towards her, in particular, the comments they passed during the lessons and during their study period, which implied that she was inferior compared to them. She wrote her questions down and would then ask the teacher later or ask other female students who were in the final year of A-level. S3 usually performed better than male students in class tests, demonstrating that she was exerting a lot of pressure on the male students by outperforming them as she was constructing a positive physics identity for herself in this CoP.

S8 on the other hand was learning at an all-girls school. This school was well resourced and as a result, the female students did not work in pairs but carried out the experiments individually in the laboratory. The male physics teacher was creating an enabling classroom or laboratory environment where female students were expressing their identity during classroom engagements. The teacher of S8 had more or less the same interaction time with all the female students; S8 was competing very well with other female students doing physics in terms of performance in tests.

Although the teacher of S3 could not fully control the behaviour of male students, he did, however, try to give her support as a student who was studying physics without mathematics. He made sure that S3 participated in class as she came from a different level. Opportunities and support were also provided by the male physics teachers of S1, S2, S3 and S8. This caused them to gain confidence to participate in a physics CoP.

As has been explained above, when we observed S1, S2, S3 and S8 in the laboratories doing practical and theory work, we noted that they engaged or participated fully and effectively in learning physics within an enabling CoP. This is in line with Murphy and Whitelegg (2006) who explained that social theories of learning emphasise that learning occurs as individuals engage in and contribute to the practices of their communities. From this perspective, physics classrooms can be understood as communities of learners. Female participants must be able to engage mutually with the other participants to feel a sense of belonging or membership (Wenger, 1998). To engage, they have to draw on what they do and what they know.

Generally, the teachers provided these female students with an opportunity to express and evolve their identities by helping them to actively participate in practical and theory work. The female students were all very confident in carrying out practical work and in presenting the assigned topic to the other students in a class, without any stage fright. They belonged to a CoP where they were participating fully as members. According to Wenger (2010), there is a profound connection between identity and practice. Developing a practice requires the formation of a community whose members can engage with one another and thus, acknowledge each other as participants. As a consequence, practice entails the negotiation of ways of being a person in that context. The formation of a community of practice is also the negotiation of identities (ibid.). Identity in this case can be defined as negotiated experience. We define who we are by the way we experience ourselves through participation as well as by the ways we and others reify ourselves (Wenger, 2010). Identity includes not only our knowledge and experiences, but also our perceptions of ourselves,[3] others' perceptions of us, and our perceptions of others' perceptions of us that develop as we participate in communities with one another (Van Zoest & Bohl, 2008). As such, our identities do not exist only within ourselves, but rather are strung between us and the others with whom we interact. In a sense, then, our identities (Van Zoest & Bohl, 2008, p. 320) are the "vehicles from within which we participate with others in community - vehicles that provide both potentials for and limitations to our participation, and that are modified as we learn and grow through mutual participation in joint enterprises with others." Thus, a person's own and others' perceptions of his/her location and trajectory within a community are key aspects of that person's identity in practice. Therefore, it is from observing others in a CoP that one forms an idea of how new behaviour should be performed and later this coded information serves as a guide for action in their CoPs. The author stresses that students are active participants and learners in many different CoPs, in which they have formal and informal apprenticeship opportunities to learn the common language, conventions, rituals, stories and histories valued within each community.

Wenger (1998) explains that participation in collaborative activities is closely intertwined with reification and that reifications are representations of practice which give form to experience and provide a focus for participation. This implies that meaning grows out of an interweaving of participation and reification and that without participation and practice, reifications are abstract and inert. Practice without reification leaves little to reflect upon. Physics identities therefore require negotiation and construction as female students engage positively with traditionally masculine areas of study after having developed the confidence to relate to and meaningfully interact with male peers during mutual engagement as was demonstrated when these students' behaviour was observed during classroom engagement. Having looked at the female students' participation in physics, the next section considers the influence of identity formation on perception of and participation in physics.

6.3. The influence of identity formation on perception of and participation in physics

Gender and identity formation issues are contextually embedded in culture and history of members in a community and these in turn influence our perception, thinking and practice (Wenger, 1998). Based on the stories told by participants in this study and some field notes based on classroom observations, a composite overview of their perception of physics is provided in Table 3.

All participants in this study stated that Zimbabwean culture does influence their identity formation i.e. way these female students perceive themselves. From the interview data obtained, the common perception in all the three schools confirms that the cultural background of these Zimbabwean female students dictates that physics is a masculine subject; hence it must be done by boys. All the female students both, doing physics and those doing maths only perceived physics as a masculine subject, being influenced by the way the female students see themselves (identity).

The students, S1, S2, S3 and S8 who were doing physics had formed a positive physics identity. They described themselves as *fearless* because many students, especially the girls fear to fail physics which is considered to be very difficult. They described their identity as *courageous* because in the Zimbabwean culture, some parents as well as the community discourage girls from doing physics (Gudyanga, Adam, & Kurup, 2015). They were doing physics against their cultural expectations since physics (as stated previously) is considered to be a subject which should be done by boys. Although all human beings are essentially intelligent, the female students described themselves as more *intelligent* than other students not doing physics, because physics is described as a more challenging subject and the community considers anyone doing physics as more intelligent.

Students who were doing maths without physics were potential students to do physics but chose not to do physics because they had formed a negative physics identity. These students: S4 and S5 formed a negative physics identity and hence they were not courageous to go against cultural expectations. These female participants had been socialised (from an early childhood) that physics was masculine and this impacted negatively on their identity which eventually influenced their perception of and participation in physics. As alluded to previously in the literature, the GST argues that female students form organised knowledge structures (*schemas*[4]) and learn to encode and to

Figure 2. Female students enrolled for physics and mathematics or mathematics only in the co-educational schools.

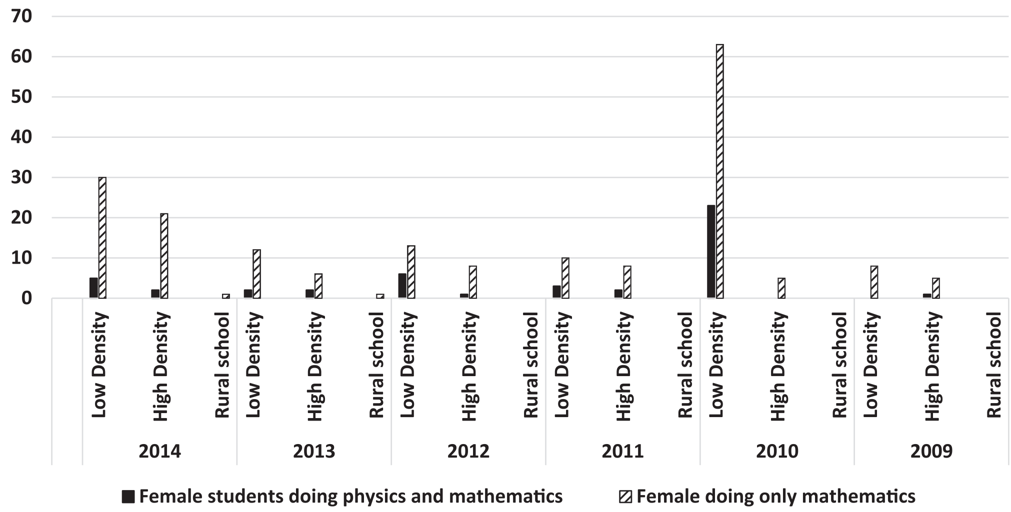
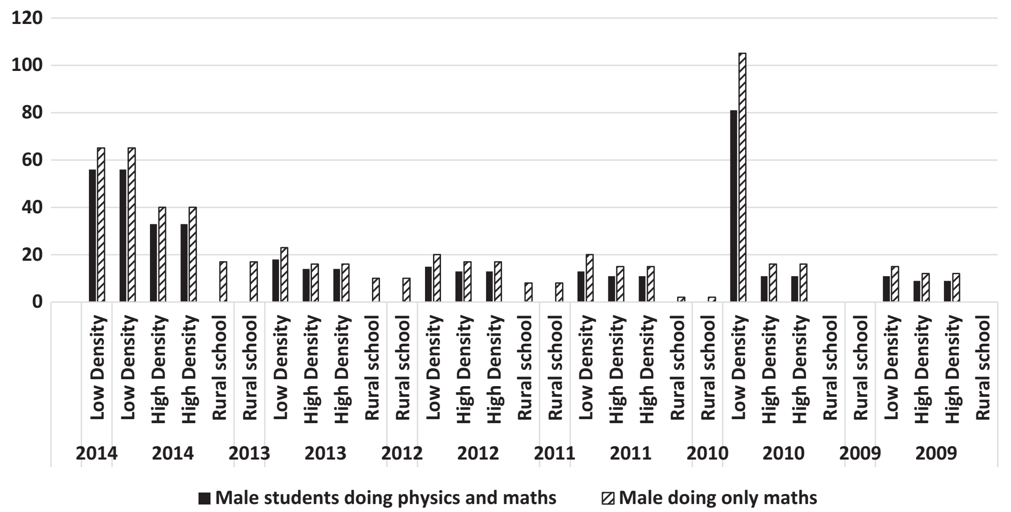


Figure 3. Male students enrolled for physics and mathematics or mathematics only in the co-educational schools.



organise information in terms of an evolving network of associations that organises and guides an individual's perception (Bem, 1983). According to Bem (1983, p. 605):

> ...gender schema becomes a prescriptive standard or a guide...that prompts an individual to regulate his or her behaviour to that which conforms to the cultural definition of *femaleness.*

Potential students to do physics did not enrol into physics classes because they had formed a negative physics identity. They did not want to study physics because it failed to conform to their cultural definition of a woman which affected their perception of physics. Their negative identity formation influenced their negative perceptions of physics which in turn caused them not to participate or to enrol into physics classes in their large numbers. In other words, the female students doing mathematics only without physics perceived physics, to be irrelevant to their future aspirations, difficult, too involving and masculine. These perceptions result in the development of a general negative physics identity to the subject and caused fewer female students to opt for physics as one of their A level subjects.

Figures 2 and 3 show the enrolment patterns of female and male students who were doing either the physics and mathematics combination or mathematics only in the co-educational school contexts for the last six years. As seen in Figures 2 and 3, the trend appears to be that more students take mathematics only rather than the usual combination of physics and mathematics whether it is males or females. More male students were doing either physics and mathematics combination or only mathematics than female students. There is a substantial difference in the number of female and male students taking either of the two combinations. However, the difference in the number of female students taking the physics and mathematics combination and mathematics only is more than in male students.

The number of male students doing mathematics is lowest in rural school compared with the low and high density schools. This may be due to the more deeply rooted cultural perception that mathematics is a hard subject. It must be noted that the rural school participating in the study did not offer physics as a subject since the school did not have adequate laboratory facilities, materials and equipment.

Parents of female students from the low density and those from all-girls schools are more educated than parents from high density and rural schools. Most of these parents are professionals of middle socio-economic status, who earn above 400 United States dollars per month. These educated parents encourage their children to study science subjects. This is why the number of female students doing physics was higher in low density and all-girls schools (see Table 1). Zimbabwean parents having a higher educational level are most likely to support their children's choices of going against the norm. Zimbabwean educated parents of low socio-economic background also support their daughters' choice of studying physics emotionally but may not be in a position to support them materially due to financial constraints. Some of them may initially discourage the daughters but eventually support them if they see that they are determined to study physics and maths as expressed by S7 from a rural school doing who was initially discouraged from studying maths by her parent. From what has been described, the summary is that: on one hand, the more educated parents tend to earn more and hence send their children to well-resourced, low density schools, while on the other hand, parents of low socio-economic status are not formally educated and can only afford to send their children to high density or rural schools.

It is important to note that identity is a powerful construct for understanding student learning because identities are constructed through practice. The experiences of female students determine the way they formed their positive or negative identities, behave in class, and interact within the group. This means that the schema which individuals develop about the process of identity formation might be a product of self-construction as well as social construction. The way we are socialised affects the way we form our identities and this in turn affect our perceptions of and participation in physics and hence the way we interact within our communities of practice. Students' actions then become an expression of their social identities because it was their social identities that have organised (Lloyd & Duveen, 1992) the kind of persons that they are and wish to be in as far as their participation in physics is concerned. Our identity is shaped by our communities (Wenger, 2000).

7. Conclusion

This study found out that the Zimbabwean female students' identity formation influences their perceptions of physics as masculine and difficult which inevitably affected their participation in physics. The positive identity enabled the female participants to study physics. In other words, students who were studying physics had positive physics identity and perceived it as too involving or demanding; requiring logical reasoning; but very interesting; very important and can be practically applied to daily life. These positive identities of physics influenced them to create positive perceptions of physics as a subject. The female participants studying physics were observed during the practical and theory lessons. They were comfortable in handling apparatus and were also very comfortable in the classroom. These female participants actively carried out practical experiments which they completed within given time. During the theory lesson, some made presentations to the whole group on electromagnetic induction demonstrating understanding and meaning making. They were very confident and engaged or participated fully and effectively in learning physics within their communities of practice. These female students holding positive perceptions actively participated in their physics CoP, further shaping and reshaping their identities in the process. Female students doing only mathematics had negative physics identity. Their fear of failing, lack of confidence, the influence of family and the prevailing cultural perceptions were factors that influenced their identity formation or the way they saw themselves (identity) (Gudyanga, 2016), significantly affecting their perceptions of and participation in physics. Who one is, in the past, present and possible futures, is informed by the encounters one has as one address(es) and respond(s) to others (Holland & Lave, 2009). Gudyanga et al. (2015) argue that identity is a powerful construct for understanding student learning because identities are constructed through practice. The authors point out that female students' experiences determine the way they form their identities, behave in class and interact within the CoP, including their teachers and the way they interpret the knowledge presented. This means that the schema that individuals develop about the process of identity formation might be a product of self-construction as well as social construction. The way we are socialised affects the way we interact within our communities of practice and, hence, the way we form our identities. We argue that female students must study physics which is traditionally stereotyped as masculine to prove to society that girls and boys are not intellectually different as such. This study is important and contributes to the existing body of knowledge (mainly as it fills the gaps) in its focus on the relationship between female students' identity and their participation in physics. The findings provide a deeper understanding, both empirically and conceptually of the issue of female students' under-representation in science education within the constructs of identity and identity formation.

Through this research, it is recommended that physics teachers should be able to inspire their students by being enthusiastic about the subject and being empathetic through personal encouragement to help to lower the barrier in relation to the perceived image of physics as being a difficult subject. This perception has to be tackled by use of creative teaching and learning approaches which can make learning of physics more interesting.

8. Recommendations for further research

It is recommended that a wider and more comprehensive study nationally is warranted to confirm the findings of this study. Developing this study into a longer-term programme may therefore be interesting. Further research to explore the reasons for the common perception that physics is a difficult school subject would be beneficial.

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Author details
Anna Gudyanga[1]
E-mails: gudyangaa@gmail.com, gudyangaa@msu.ac.zw
Raj Kurup[2]
E-mail: raj.kurup@nmmu.ac.za
[1] Department of Educational Foundations Management and Curriculum Studies, Midlands State University, Gweru, Zimbabwe.
[2] Department of Education, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

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Notes

1. Prenatally or at the moment of birth.
2. A schema is a mental structure or cognitive repertoire, which contains general expectation and knowledge of the world.
3. i.e. our values, beliefs, desires, motivations and self-identifications.
4. A schema is a mental structure or cognitive repertoire, which contains general expectation and knowledge of the world.

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