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*Research Article*

# High school students' misconceptions about force: what changed the flipped class experience?

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**Abstract**

Misconceptions challenge science learning. This study investigated Grade eleven learners' prevalent misconceptions about force using Force Concept Inventory (FCI) and learners' experiences of using flipped class. The sample comprised 190 learners for FCI and 14 learners for Focus Group Discussions (FGD). A quasi-experimental design using Experimental Group (EG), which was taught using Flipped classes and Control Group (CG) taught using Talk and Chalk method (TCM). Descriptive statistics, concentration analysis, t-test and thematic analysis were used to analyse data. Results show an 81.8% prevalence of misconceptions in seven categories. The most common patterns of misconceptions were Low and Low (LL) and Low and Medium (LM), while the least included Medium and Medium (MM). Two themes emerged from FGD: interesting learning about Isaac Newton's background and identifying their incoherent knowledge of the force. It suggests that using flipped classes minimised misconceptions and created interest in science for gifted and less gifted learners, which resulted in improved learners' performance.

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## Introduction

Misconceptions are a challenge to learning physics for all learners including the gifted learners. Misconceptions are incorrect understandings of concepts, objects and events (Martin, Sexton & Gerlovich, 2001), which impede learning (Chew, 2005). Learners display misconceptions about force during Grade 12 high-stake examinations (Department of Basic Education, 2012). It implies a need to identify misconceptions per topic at an early stage (Williams, 2009) using Force Concept Inventory (FCI) and address them (Sands et al. 2018). FCI is a low stake assessment tool that is valid, standardised and used for longitudinal studies (McGrath et al. 2015). Therefore, investigating misconceptions using FCI and flipped classes to improve learners' performance including the gifted learners can be a giant in science education. Unfortunately, there are few flipped classes conducted in South Africa secondary schools with both gifted and less gifted learners. This study contributes to learners' misconceptions prevalence regarding force using FCI and to establishing gifted and less gifted learners' experiences of using flipped classes to minimise misconceptions.

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## Literature Review

### Force Concept Inventory

Concept inventories are diagnostic tools that measure learners' state of knowledge (Sands et al. 2018). Concept inventories provide information on learners' understanding of concepts (McGrath et al. 2015). A variety of concept inventories exist in different disciplines (Gavin-Doxas & Klymkowsky, 2008). In Physics, for example, the FCI is widely used to assess learners' understanding of mechanics (Martin-Blas et al. 2010). The findings from FCI may assist teachers in recognising conceptual coherence (Savinainen & Viiri, 2014).

### Misconceptions

Literature shows that learners' initial naïve ideas usually persist unless those ideas are challenged (Williams, 2009). Learners have varying levels of inaccurate knowledge and incorrect beliefs known as misconceptions (Hughe et al. 2013). In previous research, other terms have been used synonymously with misconceptions: preconceptions, naïve beliefs (Mayer, 2002), alternate conceptions (Aikenhead, 2006), personal models of reality (Wiser & Amin, 2001) and unfounded beliefs (Zirbel, 2004). These misconceptions hamper learners' performance.

### The Flipped Class

The Flipped Class is a digital technology used to provide content when learners are not in classroom (Jamaludin & Osman, 2014). This approach provides great flexibility for learners to internalise the content (Bergman & Sams, 2012). The current generation of learning is excited to use technology to learn (Agyei, 2021). It is no wonder Mishra and Koehler (2006) contend that effective teaching should embrace Technological, Pedagogical and Content Knowledge (TPACK).

### Methods of Minimizing Misconceptions

Methods used to minimise misconceptions include Topic Specific Pedagogical Content Knowledge (TSPCK) (Rollnick & Davidowitz, 2015, Sands et al. 2018), where learning difficulties and misconceptions per topic are identified, and a solution is devised to ease learning. Conceptual Change Model (CCM) (Furqani et al. 2018; Zakiyah et al. 2019) were Predict-Observe-Predict (POE) approach that yielded better conceptual understanding in biology. Problem-Based Learning (PBL) (Sutton & Knuth, 2017), and Flipped classes (Williams, 2016) where a specific activity is designed for gifted and less gifted learners to do, which aims at minimising misconceptions.

### Research Problem

Before coming to school, learners hold different misconceptions (Vosniadou & Brewer, 1992), which are deep-rooted and resistant to change (Morrison & Lederman, 2003). The challenge is that physics science teachers in South Africa rarely identify learners' misconceptions and their prevalence using FCI to select a suitable method. If gifted and less gifted learners' misconceptions are not addressed, conceptual understanding of science concepts will be curtailed.

### Purpose

The purpose was to identify Grade 11 learners' misconceptions prevalence using Force Concept Inventory (FCI) and establish learners' experiences of Flipped class in Maraba Circuit.

### Research Questions

The research was to answer two questions:

- What are the prevalent Grade 11 learners' misconceptions regarding force concept?
- What are the girls' experiences of studying forces using flipped classes?

## Method

### Research Design

This research employed both quantitative and qualitative approaches (Creswell, 2013). These approaches were suitable because the researchers wanted to identify misconceptions and their prevalence. The quantitative approach used a survey and quasi-experimental designs to identify misconceptions and their prevalence among learners, while flipped classes minimise misconceptions. The qualitative approach sought to establish learners' experiences when studying Force in the South Africa context.

### Participants

The population comprised 329 learners from eleven schools in Maraba Circuit, Limpopo of South Africa. A random sample was used to obtain five schools. Yamane (1967) formula below was used to arrive at the minimum acceptable sample of 180 minimum sample size (95%) confidence interval.

$$n = N / (1 + Ne^2)$$

where n represents sample size, N is the known population, and e is the error level. The sample obtained was 190 and was deemed sufficient to represent the population of Maraba Circuit in South Africa since it was more than 180.

**Instrument and Procedure**

The FCI was developed in 1985 (Hestenes et al. 1985) and underwent extensive trials and refinements (Han et al. 2015). The FCI comprises 30 items that assess understanding of Force. The reliability of FCI has been challenged. Lasry et al. (2011) contend each item of FCI has low reliability, but not the whole instrument. The internal consistency reliability using Kuder-Richardson (K-R20) was between 0.84 and 0.88 for pre-test and post-test, respectively (Persson, 2015). Hence, FCI is construed to measure a unique construct in Physics (Lasry et al. 2011) such as misconceptions prevalence (Bekkink et al. 2016).

FGD interviews (Appendix 1) were conducted to elicited learners' understanding and triangulated the quantitative data (Ehlers, King & Ziyani, 2004; Denzin, 2012). The FGD comprised 14 learners, 6 gifted and 8 less gifted, purposively selected based on the exhibited levels of misconceptions. According to Merton et al. (1990), the number for FGD can range from 12 to 15. For face validity, FGD questions were checked by two teachers, and their recommendations were used to make changes.

FCI was administered to 190 Grade 11 Physical Sciences learners from Maraba Circuit. FGD was held with two groups about where and when they learned about Isaac Newton. Learners were given real-life scenarios regarding force. The discussion stopped in the third session after reaching a saturation point (Krueger, 2002). All the discussions were audio-recorded.

Two classes comprising 41 randomly allocated to Experimental Group (EG), and Control Group (CG) in a quasi-experiment were used for the study. The EG was taught for three weeks using Flipped Classes, where learners viewed videos regarding force before coming to class, while CG used the Talk and Chalk method (TCM) for three weeks. After three weeks, both groups were tested to ascertain their performance. FCI questionnaires were used for pre- and post-test, but the post-test questions were rearranged to minimise recognition.

**Data Analysis**

Quantitative data were analysed using Concentration Analysis. The prevalence of misconceptions was calculated according to the following formula (Roe & Doll, 2000).

$$Prevalence = \frac{frequency\ of commonest\ \ incorrect\ response}{sample\ size} x\ 100\%$$

The average prevalence $P_{av}$ for all misconceptions identified was calculated using the following formula:

$$p_{av} = \frac{\sum p_i}{n}$$

*where* $p_{av}$ = *average prevalence,* $p_i$ = *prevalence, and n = number of misconceptions* in a group.

The different choices 190 learners made in FCI were used to calculate the Concentration Factor (C), the learners' selection between the correct choice and the distracters ranges from 0 to 1. Value 0 is the probability that all 190 learners selected A-E choices equally for one item, and value 1 is where all responses concentrate on one correct option (Bao & Reddish, 2001). The concentration factor (C) was calculated using the equation of Bao and Reddish (2001):

$$C = \frac{\sqrt{m}}{\sqrt{m}-1} \times - (\frac{\sqrt{\sum_i^m n^2}}{N} - \frac{1}{\sqrt{m}}$$

where $m$ connotes choice numbers A to E, $n$ represents the number of learners choosing an option, $N$ is the sample. To identify whether learners selected choices guided by force knowledge or random guessing, the correct answer scores (S) were normalised to the interval [0, 1]. The score was categorised into three levels: Low (L) = 0 ~ 0.4); Medium (M ) = 0.4 ~ 0.7); and High (H ) = 0.7 ~ 1.0). Similarly, for C values the three levels were Low (L) = 0 ~ 0.2); Medium (M) = 0.2 ~ 0.5); and High (H) =0.5 ~ 1.0) (Bao & Reddish, 2001). The S-C patterns range from Low Score-Low Concentration (LL) through Medium Score-Medium Concentration (MM) to High Score-High Concentration (HH) pattern.

Data from quasi-experiment were analysed using a t-test to find out the differences amongst EG and CG for pre- and post-tests. Finally, audio recorded qualitative data from FGD was transcribed by playing it many times to pick the participants responses; the transcripts were read and re-read to identify specific contextual ideas (Krueger, 1994) and similar ideas were identified and grouped into themes.

## Results

### Quantitative Results

### Grade 11 Learners' Misconceptions Prevalent the Misconceptions Regarding the Force Concept

Seven categories of misconceptions were prevalent and their prevalence percentages are presented (Table 1).

**Table 1**

*Seven Categories of Prevalent Misconceptions and Their Prevalence Percentage*

| Misconception category | Inventory Item | Frequency | Prevalence (%) | Average Prevalence $p_{av} = \sum \frac{p_i}{n}$ (%) |
|---|---|---|---|---|
| Gravity | 1 | 146 | 76.8 | 78.4 |
| | 2 | 153 | 80.5 | |
| | 4 | 123 | 64.7 | |
| | 13 | 174 | 91.6 | |
| Active forces | 3 | 143 | 75.3 | 81.8 |
| | 5 | 161 | 84.7 | |
| | 26 | 162 | 85.3 | |
| Impetus | 1 | 146 | 76.8 | 85.4 |
| | 5 | 161 | 84.7 | |
| | 10 | 161 | 84.7 | |
| | 11 | 165 | 86.8 | |
| | 13 | 174 | 91.6 | |
| | 18 | 161 | 84.7 | |
| | 30 | 168 | 88.4 | |
| Combination of influences | 8 | 137 | 72.1 | 83.8 |
| | 17 | 150 | 78.9 | |
| | 21 | 180 | 94.7 | |
| | 23 | 170 | 89.5 | |
| Kinematics | 14 | 172 | 90.5 | 91.7 |
| | 19 | 175 | 92.1 | |
| | 20 | 176 | 92.6 | |
| Other influences on motion | 6 | 163 | 85.8 | 81.3 |
| | 7 | 155 | 81.6 | |
| | 25 | 151 | 79.5 | |
| | 27 | 149 | 78.4 | |
| Action/Reaction pairs | 4 | 123 | 64.7 | 70.0 |
| | 28 | 143 | 75.3 | |
| Average | | | | 81.8% |

Table 1 summarises the average prevalence of each of the seven misconception groups ranging from 70.0% (Action-reaction pairs) to 91.7% (Kinematics) and an average misconception rate of 81.8% was achieved.

The FCI diagnosed learners' misconceptions. The identified misconceptions, Scores, Concentration Factors and Score-Concentration (S-C) prevalence were calculated according to Roe and Doll (2000) (Table 2).

**Table 2**

*Misconceptions Held by Learners in %, Scores (S), Concentration Factor (C) and S-C pattern*

| Item | A (%) | B (%) | C (%) | D (%) | E (%) | Correct Answer | Score (%) | S [0-1] | C[0-1] | S-C Pattern /Model |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 27.4 | 15.8 | 23.2 | 23.2 | 10.5 | C | 23.2 | 0.23 | 0.00 | (LL) |
| 2 | 19.5 | 32.1 | 26.8 | 13.7 | 7.9 | A | 19.5 | 0.20 | 0.13 | (LL) |
| 3 | 7.4 | 37.9 | 24.7 | 2.6 | 27.4 | C | 24.7 | 0.25 | 0.29 | (LL) |
| 4 | 41.1 | 4.7 | 8.9 | 10.0 | 35.3 | E | 35.3 | 0.35 | 0.37 | (LM) |
| 5 | 14.7 | 15.3 | 28.9 | 20.5 | 20.5 | B | 15.3 | 0.15 | 0.05 | (LL) |
| 6 | 18.9 | 14.2 | 13.7 | 13.2 | 40 | B | 14.2 | 0.14 | 0.18 | (LL) |
| 7 | 17.9 | 18.4 | 18.9 | 7.9 | 36.8 | B | 18.4 | 0.18 | 0.15 | (LL) |
| 8 | 28.9 | 27.9 | 18.4 | 14.7 | 10.0 | B | 27.9 | 0.28 | 0.10 | (LL) |
| 9 | 11.6 | 36.8 | 14.7 | 10.0 | 26.8 | E | 26,8 | 0.27 | 0.18 | (LL) |
| 10 | 15.3 | 16.8 | 6.3 | 47.4 | 14.2 | A | 15.3 | 0.15 | 0.33 | (LM) |
| 11 | 4.7 | 33.2 | 41.6 | 13.2 | 7.4 | D | 13.2 | 0.13 | 0.35 | (LM) |
| 12 | 17.4 | 33.7 | 26.3 | 22.1 | 0.5 | B | 33.7 | 0.34 | 0.21 | (LM) |
| 13 | 18.4 | 40.0 | 20.5 | 8.4 | 12.6 | D | 8.4 | 0.08 | 0.20 | (LM) |
| 14 | 30.0 | 42.1 | 13.7 | 9.5 | 4.7 | D | 9.5 | 0.10 | 0.32 | (LM) |
| 15 | 38.4 | 24.7 | 21.1 | 14.2 | 1.6 | A | 3.84 | 0.38 | 0.25 | (LM) |
| 16 | 38.9 | 14.7 | 23.7 | 10.5 | 12.1 | A | 38.9 | 0.39 | 0.19 | (LL) |
| 17 | 36.3 | 21.1 | 17.4 | 15.3 | 10.0 | B | 21.1 | 0.21 | 0.14 | (LL) |
| 18 | 11.6 | 15.3 | 38.4 | 33.7 | 1.1 | B | 15.3 | 0.15 | 0.32 | (LM) |
| 19 | 41.6 | 10.5 | 6.8 | 33.2 | 7.9 | E | 7.9 | 0.08 | 0.34 | (LM) |
| 20 | 30.5 | 10.5 | 35.3 | 7.4 | 16.3 | D | 7.4 | 0.07 | 0.21 | (LM) |
| 21 | 15.3 | 51.1 | 20.0 | 8.4 | 5.3 | E | 5.3 | 0.53 | 0.43 | (MM) |
| 22 | 26.3 | 35.3 | 6.3 | 23.2 | 8.9 | B | 35.3 | 0.35 | 0.20 | (LM) |
| 23 | 20.5 | 10.5 | 36.3 | 21.1 | 11.6 | B | 10.5 | 0.11 | 0.15 | (LL) |
| 24 | 37.9 | 15.8 | 27.9 | 8.4 | 10.0 | A | 37.9 | 0.38 | 0.22 | (LM) |
| 25 | 28.4 | 23.2 | 20.5 | 16.3 | 11.6 | C | 20.5 | 0.21 | 0.06 | (LL) |
| 26 | 35.3 | 24.7 | 13.2 | 12.1 | 14.7 | E | 147 | 0.15 | 0.14 | (LL) |
| 27 | 28.4 | 40.0 | 21.6 | 5.3 | 4.7 | C | 21.6 | 0.22 | 0.31 | (LM) |
| 28 | 6.3 | 22.1 | 11.6 | 35.3 | 24.7 | E | 24.7 | 0.25 | 0.18 | (LL) |
| 29 | 27.4 | 37.9 | 17.9 | 3.7 | 13.2 | B | 37.9 | 0.38 | 0.24 | (LM) |
| 30 | 10.5 | 21.1 | 11.6 | 25.8 | 31.1 | C | 11.6 | 0.12 | 0.11 | (LL) |
| | | | | | | Average | 21.1% | | | |

Table 2 shows that 21.1% of the learners correctly answered FCI items. The most common S-C patterns were Low Score-Low Concentration (LL), Low Score-Medium Concentration (LM), and there was only one item which represented Medium Score-Medium Concentration (MM) and none in the High Score-High Concentration (HH) pattern.

The Concentration Factors (C) were plotted against the Scores and are presented in Figure 1.

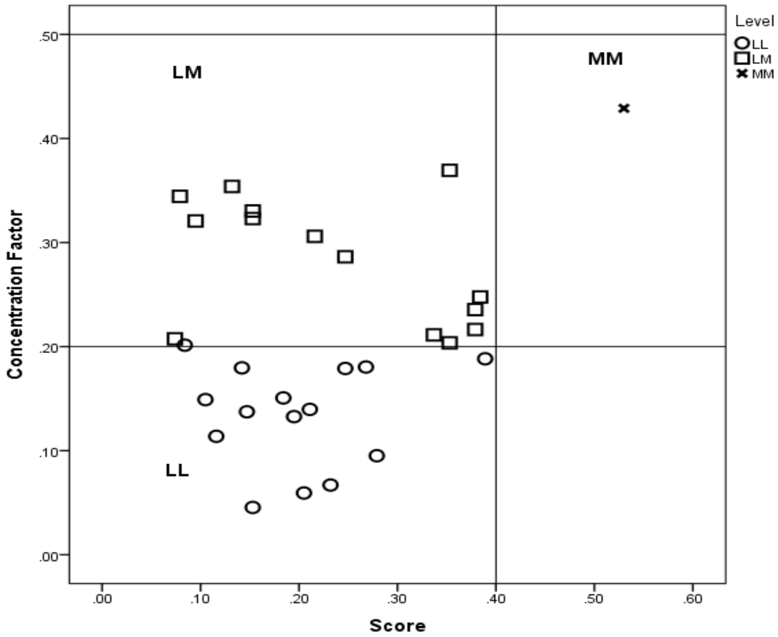


**Figure 1**

*Concentration-Score Plot of Choices Between Correct Answers and Distractors on FCI items*

Figure 1 shows that fifteen responses were in the LL, fourteen in the LM, one in the MM and none in HH levels.

**Table 3**

*Post-test Results for CG and EG of Flipped Classroom*

| Group | Number | Mean | SD | T-test | *p* |
|---|---|---|---|---|---|
| Control | 41 | 12.98 | 25.12 | 7.63 | 0.00* |
| Experimental | 41 | 19.66 | 11.06 | | |

The results from the quasi-experiment show the Flipped class (mean = 19.66; 11.06 SD), while the control class which did not use Flipped classes (mean = 12.98;25.12SD). These values were significantly different amongst pre- and post-test in the Flipped classes, suggesting that Flipped classes minimised misconceptions and improved performance in EG but not in CG, which did not use Flipped classes (t = 7.63; p<0.05).

**Qualitative Research Results**

Questions 2: What are the learners' experiences of learning Force using Flipped class?

While quantitative data provides misconceptions and their prevalence, the qualitative approach provides learners' experiences of Flipped classes. Two themes emerged: interesting to learn about Isaac Newton's background, and identifying their incoherent knowledge of Newtonian Physics.

**Theme 1:** Interesting learning about Isaac Newton's background.

FGD delved into the history of Newtonian laws. First, learners were required to explain their views regarding Isaac Newton and learn about him. After that, they shared their experiences of using Flipped classes. Verbatim statements on the concluded issues are reported from FGD Session one: *"He was the first person to discover that there's gravitational force by seeing an apple fall when there was no wind". "We know Newton to be a person who came about with three laws of physics, that is Newton's law of motion one, two and three, and the law of universal gravitation."*

FGD sessions dealt with learners' knowledge of Newton as a person and concluded that Newton was the first person to discover gravitational force by observing an apple falling when there was no wind and formulated three laws of motion.

**Theme 2:** Identifying their incoherent knowledge of Force.

FGD sessions two and three are reported here below. Session two: A box is being pushed along a smooth horizontal surface with constant force. The applied force is removed. Describe the motion of the box. Next are verbatim statements agreed upon: *"It will constantly move until it stops because it's on a smooth surface, and there's less friction". There must be a force or an external source of power.*

*"It will move a little then stop. The stopping is because of less friction on a smooth horizontal surface. So, if it goes forward it will not stop immediately, it will move until friction stops it*

Also:

*"And when there is friction, it acts opposite to the applied force. Friction acts opposite to the applied force. Since the applied force has been removed, there's no way that it can continue moving. And immediately when you leave the box, friction opposes its motion. So, it will just stop, unless it was on a steep path."*

It was concluded that an object moves if there is an applied force to overcome friction. Thus, motion in one direction is opposed by friction unless a slope will compensate for the friction.

Still, during session two, a second task was: On a rainy day, friction was negligible. A car moves with constant velocity and a straight level (tarred) road that curves sharply towards the end. Explain the motion of the car. Learners explained: *"Because of Newton's second law which states that when a resultant force is exerted on a body, it causes the body to move towards the exerted force. Newton 1 and 2 apply."*

Also, for them to understand the content they stated that *"an approach was interesting because it allowed us to manipulate apparatus and find solutions to understand everyday life problems."*

The session concluded that: *"If the driver does not 'do something' the car will go straight and not curve with the road."*

FGD session two concluded that an object moves toward force applied according to Newton's laws one and two and that the driver should stop the car from going straight.

Session three, the task was: A big truck collides head-on with a small car. What can you say about the force a truck exerts on the car compared to the car's force? A few learners correctly applied the third Newton's law. *"They're equal but opposite in direction."*

Majority of learners expressed: *"Force applied to a small body by a big body* is bigger than the reaction force *applied to big body by the small one."* Others responded: *"The mass of the truck is high, and the mass of the car is small so the small car would be crushed."*

FGD session three considered a force to be related to the size of the object. The truck has more mass than a small car. Therefore, during a truck and a small car crash, the small car will be crushed more.

Another task for FGD session three was: An object is thrown vertically upwards. Identify the forces acting on a body that is thrown by a hand. Also, compare the object's speed when it is going upwards and its speed when it comes downward. The following are the conclusions made: *"When it is up there, it will have a speed limit. When it gets up, it will stop somewhere because there is nothing that pushes it anymore. Then it will return because of gravity."*

*"By throwing the object up, you exert a force on it. When it returns, there is no person or anything that is pushing it down."*

Also,

*"Because it was given a start, it goes up; it goes with a certain high velocity. Then when it comes back because gravity will be pulling it, it will come down, but the speed is not the same, it is less than when you threw it up. Applied force goes in the same direction as normal force."*.

On how to ease the understanding of the force concept, it was stated that "*Tasks were very interesting and easy to understand, but more activities are needed like solving real everyday human challenges."*

FGD session three concluded that a projectile move upwards because it is being pushed up and returns under the force of gravity at a different velocity than upward motion. It was noted that if a learner missed one question on a specific concept like motion or mass, that learner was most likely to miss other questions in the same sequence.

## Discussion and Conclusion

The study sought to identify Grade 11 learners' misconceptions prevalence using the Force Concept Inventory (FCI) and establish learners' experiences studying force using Flipped classes to minimise the identified misconceptions. The results show learners had a high prevalence of misconceptions (Table 1 and 2). Flipped classes created interest in learners to examine their everyday ideas incoherent with science because misconceptions increased the chances of missing the acceptable answers (Scott & Schumayer, 2018).

Identify misconceptions were addressed using flipped class, which minimised misconceptions. Results from Flipped classes suggest that the teachers' Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK) affected learners' experiences. This observation agrees with Scott and Schumayer (2018), who contend that instructions designed to minimise misconceptions were positively correlated with improvements in the learners' conceptual understanding of science. It is no wonder some learners performed well and had a desire to continue studying science.

The low score (S) and the low Concentration factor (C) suggest that learners had no clear understanding of Force. These results mirror Hestenes, Wells and Swackhamer (1992), where one group of learners scored an average of 20%, while another group scored 23% on the FCI. The S-C plot exhibits low Scores and concentration factors with 50% as LL and 47% responses with LM and 3% in the MM domain (Figure 1). These results suggest that learners' answers were in two patterns: low (LL/LM) and medium (MM) (Figure 1). It may imply a dominance of random guessing when answering questions on FCI (Bao & Reddish, 2001). These results suggest that the teaching did not assist learners to recognise the distractions in FCI. Hence, the majority (190) learners could only answer the FCI in the LL and LM domains, with very few in the MM area (Table 2, Figure 1). These results corroborate the poor science performance at national public examinations in South Africa (Onwu & Stoffel, 2005; Department of Basic Education, 2014) and the outcomes of the Third International Mathematics and Science Study (TIMSS) (Gonzales et al. 2004). In this research, the poor performance on Force may suggest a poor sequencing of topics and the lack of practical work in some schools in Limpopo Province (Dudu & Vhurumuku, 2012). Also, Spaull (2013a; 2013b) shows that systemic flaws in school science education negatively impact tertiary learning, suggesting learners have misconceptions (Zirbel, 2004). We contend that more studies should focus on identifying misconceptions in different science topics to discover other misconceptions.

In FGD, learners displayed a naïve level of understanding of force, namely: 1) constant speed and sudden stop, or 2) sudden stop and gradually slowing down. Learners understood the effect of friction; however, they did not understand the behaviour of the box after the push was removed. Two learners stated Newton's second law in the session but did not apply it to the situation. Thus, Group two concluded: "*If the driver does not 'do something, the car will go straight and not curve with the road*". These responses suggest learners did not know that the driver could change acceleration (*a*) by 1) stepping on brakes to reduce velocity (v); 2) releasing the foot from the accelerator pedal reducing fuel entering the carburettor, and 3) steering the car along the curve which changes the angle of velocity. They did not articulate that centripetal acceleration $a = (v^2/r)$ is inversely proportional to the radius (r) of the curve. Steering around a sharp curve of small radius at high velocity makes a large acceleration, which may slip wheels. The three actions must produce static friction between tyres and the road to keep the car moving along the curve, suggesting centripetal force $F_c = m\,v^2/r$ equals the static friction $\mu_s mg$ (where $F_c$ is a centripetal force, $\mu_s$ coefficient of static friction, $m$ = mass and $g$ =gravitational acceleration). Thus, the driver must brake to reduce linear velocity (v) and change the direction slowly since angular velocity $(\omega)$ is $v/r$. It is an impetus dissipation misconception reported (Scott & Schumayer, 2018). The learners could not answer question 7, which dealt with understanding impetus worldviews and required complex reasoning. This observation agrees with the learners' achievement related to teachers' sound PCK (Shulman, 1986) and TSPCK (Rollnick & Davidowitz, 2015).

During the FGD, most learners provided answers to science questions but did not explain the underlying scientific concepts, suggesting learners had a superficial understanding of the force. This finding agrees with Handhika et al. (2017), who contend learners do not understand the force concept. It implies that teaching needs inculcate understanding through meaning-making, reasoning and communication (White & Gunstone, 1992). Thus, teachers need to deal with misconceptions that hinder learners from gaining understanding.

Learners' performance from the Flipped classes suggests learners developed conceptual understudying. These findings corroborate Williams (2016) and Cagande and Jugar (2018), who contend that flipped classes improved medical students' conceptual understanding. The learners' strategy of viewing and sharing ideas regarding force concepts. Thus, the flipped class intervention minimised misconceptions in gifted and less gifted learners and improved performance. Two limitations are using one topic in physics and a small sample from a rural context.

In conclusion, learners displayed a high prevalence of misconceptions in seven categories. The high prevalence of misconceptions suggests the poor acquisition of physics content knowledge and that teachers did not identify learners' misconceptions to address them. Similarly, FGD learners explained Force using their everyday experiences, which were incoherent with science. This study contributes to an effective flipped class strategy, which created interest in gifted and less gifted learners, minimised misconceptions, and improved learners' conceptual understanding of Force. The effect of flipped classes on other topics in physics applied to a larger sample from different contexts is unknown. Therefore, further studies are needed regarding misconceptions and Flipped classes using different topics in science.

## Recommendations

### Recommendations for Applicants

While misconceptions are a challenge in learning science, they are not easily identified by science teachers and hence teachers design no strategies to address those misconceptions. The researchers recommend that:

- science teachers should use Force Concept Inventory to identify misconceptions and their prevalence among their learners
- science teachers should use different strategies to minimise misconceptions.

**Recommendations for Further Research**

- Teachers should use Flipped classes on other topics to minimise misconceptions.
- Teachers should use Flipped classes on different science topics and use Flipped classes in different subjects.

## Limitations of Study

The limitation of this study was the small sample of 190 learners from one province in the country. The other limitation is that the sample was from a rural context, and therefore, it is not clear what the findings would be from other contexts: semi-urban and urban areas.

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## Biodata of the Authors

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**Appendix 1**
*Questions for FGD Sessions*

**Questions for FGD Sessions**

**Q1.** What are your views regarding Isaac Newton?
**Q2.** When and where did you encounter Isaac Newton?
**Q3.** What striking thing do you remember about him?
**Q4.** Why do you think so? Tell me how did you come to know Newton Isaac?
**Q5.** In your understanding describe the motion of the box in question
**Q6.** If a car moves with constant velocity along a straight level (tarred) road that curves sharply towards the end, describe the motion of the car.
**Q7.** If there is a move in the direction of force applied according to Newton's law 1 and 2, considering the motion of the car, what do you think will be the action of the driver to stop the car?
**Q8.** What do you think can help you to grasp force concept and why?
**Q9.** A big truck collided head-on with a small car. What can you say about the force truck's force exerted on the car compared to the car forces exerted on the truck?
**Q10.** An object was thrown vertically upwards. Identify the forces acting on the object going up and down. Will the forces upon the object are the same until it lands or not?