University of Otago

Fight like a Physicist: Teaching Basic Physics Through the Medium of Karate

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Abstract

The practice of martial arts, particularly karate, is passed down from teacher to student. The largely relationship-focused, kinaesthetic nature of teaching karate is meaningfully different from the standard transmission method of information-sharing that occurs in the classroom. The present thesis investigated the pedagogical efficacy of practicing karate in learning basic physics. It was hypothesized that senior karate students would show a more thorough understanding of classical mechanics principles than non-karate students. I also investigated the extent to which karate can help a scientifically marginalized demographic (teenage girls) acquire knowledge of physics outside of the traditional classroom environment. Prior studies indicated that most girls tend to disengage with physics by the age of sixteen. Central to the creative component of the thesis, therefore, was the development of karate-based teaching materials for both secondary school physics students and the general public, incorporating physics lessons within martial arts instruction. As predicted, senior karate practitioners possess an intuitive understanding of classical mechanics concepts, despite having undertaken no formal study in physics. While this area of research is ongoing, preliminary results are promising in two main ways. The novel presentation method appeals to students otherwise not engaged in a formal classroom session. The kinaesthetic nature of teaching karate provides students with a relevance and context to their physics learning.
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Structure Note:
The thesis flows from the past to the present. It begins with a history of karate intended to give the reader a better sense of the learning style and environment of the traditional karate classroom. From there it moves to the present with research findings, survey work and finally ongoing experimentation. The intention is for the reader to get a sense of the organic nature of teaching in this context, with the past influencing the present work, which in turn influences future work.
Prologue

"Be gentle, kind, and beautiful, yet firm and strong, both mentally and physically." - Keiko Fukuda

In 2013, Keiko Fukuda, the last living student of Jigoro Kano, the founder of the martial art of Judo, died just short of her hundredth birthday. At the time of her death, she was a 9th Dan blackbelt. Fukuda’s 9th Dan is the highest rank ever awarded to a woman by the Kodokan, the world governing body for Judo, based in Japan (Yardley, 2013).

Fukuda studied Judo for over seventy years. She dedicated her life to the discipline, never marrying and instead saying in interviews that she was married to Judo. She had acquired a reputation as a widely respected teacher and expert in the field of kata. The kata are patterns of technical movement that are remembered and practised without physical contact. Kata are unique to the martial art being studied – in this case, Judo – and often different branches or styles of martial arts will practise different kata (or different versions of kata) which are generally aligned to a level of practitioner in the style. This means that students who are beginners are expected to be learning and working on different kata than intermediate or advanced practitioners. Each kata has a name and a specific series of movements which generally become more difficult and complex as the level of martial arts skill increases.

Originally, kata seem to have been the most accepted way for women to experience martial arts. Kata show techniques and allow for practise of balance, fitness, and mental awareness without the physical contact considered by some traditional practitioners to be unsuitable for women (Miarka, Marques & Franchini, 2011). When Fukuda began her study of Judo with Kano, this study of kata was the only facet of the martial art available to women, since “fighting” (i.e., physical contact) was deemed unfeminine. By the 1960s, however, women were allowed to practice physical contact (Miarka et al., 2011). Fukuda travelled the world
teaching Judo and taught the martial art right up to her death. In 1990, Emperor Akihito awarded her the extraordinary title of National Living Treasure of Japan (Romer, 2012).

Yet, despite her many accomplishments, Fukuda was 93 years old before she was granted the rank of 9th Dan. She died only six years later, having never attained the highest rank in Judo, the 10th Dan. In fact, after Fukuda was granted a 5th Dan black belt in 1966, the Kodokan decided that women did not need any rank over 5th Dan and Fukuda was not promoted again for 30 years when this gender-biased ruling was overturned (Romer 2012; Yardley, 2013). Such treatment would have been unimaginable for a male of the same ability.

The same sense of male dominance and male privilege has wended its way through the history of martial arts in general. In karate, for instance, it still seems remarkable when a woman is graded highly, such as when, in 2013, a British woman named Linda Marchant became the only woman in the history of the International Okinawan Goju-Ryu Karate Federation to reach 7th Dan Black Belt. The story made national headlines as well as online karate information and news sites (Henderson, 2013). Yet a 7th Dan is an honour bestowed on males without similar fanfare, and there are two men within my own organisation in New Zealand, presumably much smaller than the British organisation, who have attained this rank.

The story of women in martial arts history is traditionally reduced to a few token, high-profile figures who appeared as exceptions to the rule of male dominance. They disappear quickly, replaced by the great men of the day (Fain, 1995). Yet the true history of women in karate may be difficult to ascertain, as it is mostly made up of anonymous female figures who were overshadowed by their male peers (Nower, 2007). When karate was evolving in Okinawa, women were writing in Japanese, demarking their low social status. (By contrast, noblemen of that era communicated in Chinese.) (Nower, 2007). However, it is interesting to note that Gichin Funakoshi, known as the father of the traditional Shotokan style of karate, considered
karate a discipline easily acquired by everyone, and in the early 20th century, he recommended it especially for women (Sforza et al., 2002). Indeed, the scarcity of women in martial arts is due largely to Japanese culture, which presupposes that women are meant to be fragile, gentle and submissive, with the ultimate goal of motherhood (Miarka et al., Feld 2011). It does not, it itself, reflect a lack of interest or suitability of females for the sport.

Despite its dubious history, today’s females seem to be embracing karate. In my own experience, more and more female competitors are at tournaments every year, representing a wide range of ages and talent. Out of curiosity, I surveyed my own secondary school female students to see what they thought about karate as a sport for girls. These students were unanimously positive, stating they liked karate for reasons such as, “you learn to defend yourself”; “you try things you never thought you could”; “I like competing”; and “it’s fun and interesting.” Of particular interest was the fact that more than one student commented on the mentoring aspect of the sport, with several girls stating that they liked me as a teacher.

Indeed, research has shown that developing a supportive relationship with one’s teacher is an important learning tool for girls (Mosatache, Matloff-Nieves, Kekelis, & Lawner, 2013). In the United States, education scholars studying science, technology, engineering and maths (known as the “STEM” subjects) concluded that effective teachers for girls need to understand adolescent issues and contemporary teenage culture, be non-judgemental, have a sense of humour and demonstrate good problem-solving strategies (Mosatache et al., 2013).

This is an especially important issue for girls who have disengaged with school. The martial arts classroom can be seen as a place where such students stand alongside a trustworthy adult or teacher and work with that person to help them to develop skills. This, as opposed to the more traditional “us vs. them” authoritarian dynamic found in traditional classrooms. Martial
arts also arguably appeals to girls’ sense of teamwork and belonging while allowing them to work with the teacher in a more supportive, personal setting than the traditional classroom.

In fact, in the karate world, considerable emphasis is placed on the importance of relationships and lineage. Relationships with your mentors and fellow students are central. “Lineage” is not thought of in the hereditary or familial sense as we think of that term colloquially; rather, it is a pedagogical link from teacher to student. If you are a worthy student, you will be taught, and in turn it is your duty to find worthy students of your own. In this way, knowledge and history of the sport are passed down from generation to generation.

The important point is that the traditional relationship-based format of martial arts instruction dovetails with findings showing that girls benefit from a similar structure in pedagogy.
Introduction

What is Karate History?

“The ultimate aim of Karate lies not in victory nor defeat, but in the perfection of the character of its participants.” – Gichin Funakoshi

To a karate practitioner, lineage is essential. Anyone can go to a martial arts supply store and buy a black belt. To those who take the sport seriously, though, relationships with the people you train with, including the person who bestowed the belt upon you, are more important than the belt itself. These social factors are vital to inspiring one’s personal growth, philosophy of self-defense and overall sporting excellence. As factors within a coherent whole, these are methods for personal development rather than goals in and of themselves.

What is passed down from teacher to student over time can be a diluted form of this “secret” knowledge, flavoured with the personal experiences and ideas of the teacher. This acquired information is something that is filtered through the interpretations of your teacher, and theirs before them, and so there is inevitably variation (and hence evolution) in what is taught. However, when it comes to the earliest beginnings of karate as a proper martial art, there are several theories. Some are disputed but are still pervasive enough that they are told and handed down across generations, which betrays something intrinsic about their lingering story-telling appeal. For academics and karate scholars, the greatest challenge is to reconcile anecdotes and apocryphal stories with historically provable facts and events (McCarthy, 2008).
**Goju Ryu Karate History**

Several basic facts have been established. We know, for example, that the martial art te (hand) was first practised on Okinawa or the Ryukyus, a chain of volcanic islands stretching from Japan to Taiwan. This geographic area held strategic importance for the region.

According to a 1458 inscription cast on a large bronze bell once displayed prominently at its port of entry, “Ryukyu is located in a superb position in the southern ocean. It gathers to itself the excellence of Korea. It treats Great Ming as a close associate and with Japan it is as close as lips and teeth. It is the Island of Eternal Youth that arises from their midst. With its ships, it acts as a bridge between the myriad lands. This is the country filled in all directions with exotic goods and rich treasures” (see Nelson, 2006). Today, a replica of this bell hangs at Shuri Castle in Naha, Okinawa, the traditional capital city of the Ryukyu Kingdom.

Due to their strategic position south of the main islands of Japan and close to China, these tropical islands are heavily influenced by Chinese culture, despite their being under Japanese control. Initially an independent kingdom called the Ryukyu Kingdom, there is written evidence of the islands and people in Japanese history as far back as the sixth century. The Japanese largely believed that the Okinawans were barbarians and peasants, yet they still needed the islands as a trade route to China and so their relationship was generally peaceful.

The practise of the martial art te was something learned through families, and variations in style and other characteristics reflected different kinship traditions. One of the most influential events in the development of these styles was said to be the arrival of Tametomo
in the 11th century. Tametomo was the son of a Japanese feudal warlord, a fierce warrior in his own right who is said to have stood over seven feet tall (McCarthy, 2008).

Although Okinawa’s first recorded contact with China was in the sixth century, it was not until the 1300s that the Chinese began emigrating to Okinawa. Thus began a change to the art of tea, one which incorporated the Chinese martial arts. By 1393, a Chinese settlement was established in Naha, which is now the capital of Okinawa prefecture. This was called the Thirty Six Families. For the next five centuries, Okinawan nobles could learn Chinese language and manners in this unique place. Scholarships from the Chinese government were even made available for Okinawans to study in mainland China. Many scholars believe that this centre of Chinese culture is where Chinese martial arts were initially taught to the Okinawans and became incorporated into their own fighting systems (McCarthy, 2008).

Sakihara (2009) has likened the islands of Okinawa to an offshore reef submerged at high tide and visible at low tide. In other words, Okinawan self-governance and control waxed and waned for centuries, fluctuating in accordance with the volatile strength of the central Japanese government. Whenever the Japanese government was powerful, the borders of Japan would reach to include Okinawa, and thus the “high tide” would engulf the islands in Japanese culture and influence. By contrast, whenever it was in a weakened state, the islands would emerge with their own identity outside of Japanese rule (Sakihara, 2009).

One defining moment in this tide-like relationship was the invasion of Okinawa by Japan in 1609. This was a time when the government in Japan was strong and control of Okinawa was seen as essential for the ruling Tokugawa shogunate. While the Ryukyus were allowed to retain their own king under the rule of Tokugawa, nationwide laws and edicts in Japan were enforced in Okinawa. This continued into the next government in 1867, when the Meiji rulers
replaced the Tokugawa. The Meiji stripped the Ryukyus of even a pretence of independence and enforced a heavy-handed Japanese rule over the people (Sakihara, 2009).

From approximately 1609 onwards, the Okinawans were banned from practicing martial arts of any kind and also banned from owning or carrying weapons. This was to ensure that an uprising against Japanese rule was impossible. Some believe that this ban lead to two critical developments in martial arts history. First, the practise of martial arts was forced “underground” and, as a consequence, there is very little recorded history about karate during this time. Secondly, the art of Kobudo, or martial arts with weapons, began to evolve, with most of the weapons consisting of easily disguised farm implements such as the sai (hayforks), tonfa (mill-wheel handle) and bo (6-foot staff). This is a theory that has been debated by scholars, however, some of whom believe that the similarity of weapons in Chinese martial arts point to the origin of kobudo being Chinese (McCarthy, 2008).

In the late 1800s, an Okinawan student named Kanryo Higaonna travelled to China to learn more about Chinese martial arts. There, he studied Kung Fu, eventually returning home with this knowledge. This is considered the beginning of karate as we know it today. Higoanna was known as a teacher of two disciplines. At home, he taught Naha-te, an old-style “one strike, one kill” technique in the familiar style of centuries earlier. He also taught a new style of karate for students at Naha Commercial High School (Cogan, 2003). It is important to note that his students in early 20th century Japan would have been almost exclusively male.

Education beyond primary school at the time was optional for girls, with only 8 percent of females attending high school. In addition, girls and boys were educated separately, so it is likely that there would have been no girls in Higoanna’s early classes (Anderson, 1975). The class at Naha High School is said to have been an adaptation of his martial arts knowledge, one simultaneously providing students with a physical, intellectual, and moral education.
One of the most well-known of Higoanna’s students was Chojun Miyagi. Miyagi began his martial arts training at the age of 11, and at 14, he began his tutelage under Higoanna. Miyagi grew to become a highly respected martial artist and teacher. His primary philosophy was that karate was training for the mind. It is Miyagi who emphasized the tenant that there are no first strikes in karate. Rather, according to him, karate is the art of self-defense. Miyagi’s techniques were eventually named Goju Ryu, which means “hard-soft.” Miyagi’s system of martial arts had no official name until one of his students, Jinan Shinzato, was performing a demonstration in mainland Japan and was asked what the style of karate he practised was called. His response “Goju-Ryu” was based on Miyagi’s belief that both hardness and softness were needed in karate – as in life. Miyagi himself then began using this term for his karate style (Cogan, 2003).

Miyagi died of a heart attack in 1953 at the age of 65, but his former students have students of their own now. One of Miyagi’s few still-living protégés is 83-year-old Kiichi Nakamoto. Nakamoto is the current head of the Goju Ryu Kyokai, an international branch of karate that studies traditional Okinawan Goju Ryu and Kobudo. Nakamoto is a 10th Dan in both karate and kobudo, and began his own study of karate at the tender age of six. According to legend, his lifelong devotion to the sport began by peering through the fence of Miyagi sensei’s dojo, often in the pouring rain, and copying what he saw until Miyagi accepted him as a student.¹

Today, the World Karate Federation (WKF) is the largest governing body for the sport and boasts over 130 member countries. It recognizes four official styles of karate: Goju Ryu, Shito Ryu, Shotokan and Wado Ryu (WKF, 2014). It is important to note, however, that each

¹ This is a story that has been told to me directly from Kiichi Nakamoto. Fortunately, through the legacy of my own teacher and his teacher before him, I have been able to train directly with Nakamoto on several occasions as well as with his grandson Tokuma, who will be the head of the Kyokai when Nakamoto passes on. Nakamoto is an extremely nice, humble and gracious person who is a truly inspiring karate-ka. Training with him is always an incredible learning experience.
limb of the karate tree has its own branches. Even though a given karate sub-style is not recognised formally by the WKF, that does not necessarily mean that it is not valid. It simply means that it is not recognised for the purposes of international sporting competition.

The complicated history of karate reveals how martial arts have been successfully passed down from teacher to student for centuries, and it shows that, even in the face of conflict, prejudice or other outside pressures, the core student-teacher relationship is the driving force behind the continued survival of the sport. The sheer longevity of martial arts showcases the effectiveness of its teaching methods. The question at the heart of the present thesis is therefore as follows: can educators effectively transmit other information (for example, knowledge of physics) while teaching students basic lessons of martial arts?

**Intuitive Understanding of Physics**

As a female practitioner of karate, I have been fortunate to meet many others engaged in contemporary martial arts, and in my travels I have met fellow athletes from a wide range of nations. As a high school physics teacher, one thing that stood out in my mind from my interactions with experienced practitioners of karate was that, despite their formal lack of scientific training, they seemed to have an intuitive sense of the physics underlying the sport. Many of these athletes were able to execute and explain concepts that I could only attribute to their possessing a good understanding of the core principles of classical mechanics.

As an example, I watched as a very small, slight Japanese instructor overcome a much larger and younger opponent seemingly with no effort at all. When I asked him how he did this, the instructor informed me that, as a smaller person, there were two things that he needed to do to overcome an opponent. First, he placed all of his available body mass behind whatever technique he was doing, not just that of his arm or leg. He did this by ensuring that a movement (e.g., a punch) did not just come from the arm but instead started at the feet and
moved through the body in a wave motion; this culminated in his full body mass being concentrated in the strike. In physics, this is the concept of momentum, in which a higher mass at the same velocity will create greater force. Here, this expert has applied the principle as a rational choice that leads to a greater force being imparted toward the opponent. Next he informed me that he needed to take advantage of his balance. He instructed his students to “slosh” their hips in a way to find the best position for their body. The position that was the best for him would not be the best for everyone. What was really happening was that he was asking his students to determine their own centre of mass and where it sat most centrally within the stance they were performing. Physically, this would ensure that the student was at the most stable position for their unique form. From this stable position, one could then grab or impact the opponent by delivering the most effective striking or unbalancing technique. In fact, from a physics perspective, students were being shown how centre of mass and balance combined with torque, which is the concept that a smaller force at a larger distance from the pivot point can be equally as effective as a larger force at a smaller distance.

To perform at their peak ability, concepts in classical mechanics such as momentum, impulse, forces and torques must be well understood, at least implicitly, by karate masters. To develop an effective punch, for instance, the expert will attempt to increase not only the muscle mass in the forearm, but also the speed at which the punch is delivered. To master this behavioral strategy is to show an understanding of how to increase momentum. Likewise, many practitioners will say that they always try to “pull and push” an opponent at the same time to increase the effectiveness of a technique (e.g., striking to the head by pulling the head towards the self with one hand while delivering a punch with the other hand). This kind of dynamic involves what is known in basic physics as the vector addition of forces.

For both practice and competition (or WKF sport karate), the use of safety equipment and proper falling techniques offer further opportunity to explore the intuitive application of
classical mechanics in karate. For example, “break-falling” is a martial arts concept designed to help the practitioner avoid injury when falling or thrown. Martial artists practise landing by spreading limbs out, tucking in the head, and slapping the mat with the flat of the hand. Break-falling involves a relationship between force and pressure. Karate experts will attempt a conversion between linear and rotational momentum when falling. Again, this is a concept that I have heard explained repeatedly by various practitioners who lack a formal education in physics but nonetheless seem to grasp the principle at an instinctive level. For example, I have heard break-falling described by athletes as a way to prevent injury because the force of falling is spread out across the body such that impact is on non-essential parts. This is essentially a description of the pressure equation in action: pressure equals force divided by area. Here, if a competitor increases the area over which the force occurs, he or she can reduce the pain experienced.

I have also observed a correlation between level of expertise and implicit knowledge of physics. That is, that the higher level attained, generally speaking, the better the karate expert seems to understand physics concepts. This involves linking principles and explaining finer details, even though they often don’t know the technical language from physics textbooks. Indeed, some karate experts create their own language to describe what they are doing. This was evident, for instance, when I was training with highly skilled athletes in Okinawa, Japan. Often these karate experts would describe a way of increasing the effectiveness of a technique and then ascribe to it a colorful Okinawan expression. For example when discussing centre of mass and base of support in terms of one’s stability and balance, the instructor summarised it in his own language as “being mindful of centre.”
Background

The Physics of Karate

In essence, the concepts that lie at the heart of this discussion fall under the umbrella of the classical mechanics branch of physics. Classical mechanics is one of two main branches of mechanics (the other being quantum mechanics). Classical mechanics is studied at the secondary-school level in New Zealand, where I am a teacher, as well as most other countries. This is for a number of reasons. Studies of the motion of objects have been undertaken as far back as records allow, likely because classical mechanics describes (and predicts) the motion of macroscopic objects very well. Theoretical models in this area produce accurate results as long as the objects being studied are relatively large and do not approach the speed of light (which is the purview of the other main branch of physics, quantum mechanics). Since classical mechanics involve the type of objects students encounter in their day-to-day lives, it is a topic with clear relevance to the world around them. Additionally, the principles within this subfield of physics are concrete enough for students to observe in action, rather than simply theorise about them as abstract causal forces.

Over the last few decades, several investigators have attempted to understand the actual physics of martial arts by carefully analyzing punches, kicks and other movements. Older studies included strobe lights and cameras to calculate, for instance, the velocity of hand strikes (Feld, McNair & Wilk, 1979). Early research used basic experimental designs and what is now antiquated technology (Feld et al., 1979). Yet they reached similar conclusions to more recent work, which has incorporated more sophisticated equipment such as high-speed cameras and computer-aided data loggers (Gianino & Imme, 2010; Sfroza et al, 2002). Given that the calculable physics of martial arts are now reasonably well-understood, therefore, and since karate, in particular, serves as a vivid example of classical mechanics in
action, my hypothesis was that instruction in the sport may help students who are enrolled in Classical Mechanics to learn such concepts in a fun, hands-on, and innovative way.

**Formal Science Education**

The declining engagement with science and the dwindling number of students (particularly girls) who choose to continue their science education past the point where it is compulsory is an unfortunate trend. It is also one that is occurring despite the fact that girls actually appear to be achieving better than their male counterparts prior to this stage of schooling (Daly, Grant, Bultitude, 2009). The Institute of Physics in Britain has attempted to document and address this issue of declining participation of adolescent girls in physics through a series of reports and resources aimed at high school physics teachers (Daly et al, 2009).

Over my tenure of six years as a teacher who is precisely in this demographic, I have seen this female disengagement with science first hand. At the co-educational school where I taught for the first three years of my career, my physics classes were always relatively small, yet consistently had a high male-to-female student ratio. At the single-sex female school where I have taught more recently, my physics classes remain small; but additionally, they include male students from the institution’s “brother school,” students who have scheduling clashes or other issues that prevent them from taking physics classes at their own school.

Indeed, I have had to accept increasing numbers of male students simply to make class sizes viable at both schools. One potential disadvantage of doing so, however, is that the erosion of the single-sex pedagogical environment will negatively impact on the girls’ learning.

A study by Spielhofer, Benton and Shagen (2004) examined the effects of single sex vs co-education schools on learning outcomes in a number of different areas. In terms of science, the researchers found that girls in a single-sex primary school were more likely to enrol in optional science courses at the secondary-school level. In fact, girls who had attended single-
sex schools were just as likely to take sciences as were boys from the co-educational schools, and they were up to 40 percent more likely to do so than their female peers who had attended coeducational schools (Spielhofer et al., 2004).

Despite findings such as these, however, the subject of single-sex education remains a contentious one. It also has special bearing on the academic study of physics. For example, a recent large-scale meta-analysis commissioned by the Institute of Physics reviewed data from a number of different countries, examining girls’ achievements in the subject area of physics (Murphy & Whitelegg, 2006). These findings can be summarised as follows:

- Girls in single-sex schools have greater access to physics as a taught discipline.
- Single-sex schools alone do not enhance girls’ interest or motivation in studying physics; rather, it is a combination of single-sex grouping, high teacher expectations, and curriculum.

This is consistent with the first-hand accounts of physics teachers, as shown in the Daly et al. (2009) research on girls’ participation in physics classes. Murphy and Whitelegg (2006) note a need for further study to determine if girls’ experiences in co-educational classes can be enhanced with more inclusive pedagogy and curriculum changes.

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2 Anecdotally, I have seen this at work my own physics classroom. This year, I had 14 girls at Year 12. I was asked by our brother school to take 5 boys into the class. All year the girls have seemed not as lively or engaged as the students I had last year who are now in Year 13 and did not have boys in their year 12 class last year. It happened recently that the boys’ school had an event on and the boys missed several classes in a row as a group. The change in the demeanour of the girls in class was marked. They were more engaged, discussed more and, I felt, that we all had a much more productive time. It was as if, with the boys in class in such a large percentage of the class, the girls had withdrawn. The girls in class have consistently achieved a high level of submitted work and I have been happy with their progress; the difference I noticed without the boys was in their willingness to participate in class group discussions and their engagement with the other students in the class.
The idea of high teacher expectations and curricula that are specifically designed with girls’ learning in mind also highlights the importance of cultivating a positive relationship between teacher and student, similar to pedagogical methods practiced for centuries in the martial arts.

**Context Based Teaching and Learning**

A recent study of 17,000 New Zealand students, undertaken by the organisation Sport New Zealand (2012), revealed that 95 percent of girls like playing sport (Sport New Zealand, 2012). By contrast, a recent study by the Ministry of Education (2006) showed that only 49 percent of girls enjoy learning about physics. If we could show these disengaged female science students that a sport they enjoy is actually a form of physics incarnate, this may be a way to reorient them to science disciplines. I therefore sought to combine my two professional curricula—that of my physics classroom and that of my karate seminars—in an effort to demonstrate to my female students that the sport they have voluntarily chosen to participate in is, in fact, also a lesson in physics. My approach to teaching physics through karate would be an extension of the practice of “science in context.” In contextual teaching, educators seek to convey knowledge and understanding to students within a natural (i.e., relatively unstructured) learning environment, rather than simple through classroom learning.

The general consensus on contextual science teaching is that it is more effective than conventional teaching. Studies suggest several reasons for this, the main one being that students are more engaged with the content and, thus, enjoy learning science more. Keeping students motivated and interested is a large part of teaching, so the use of contexts is seen unanimously as a positive approach from this perspective (Fensham, 2009; Finkelstein, 2005; Rennie and Parker, 1996; Vignouli, Hart and Fry, 2002; Waltner, Weisner and Rachel, 2007). Furthermore, findings indicate that students understand concepts acquired from contextual teaching methods *at least* as well as they would if they had learned them in a more
conventional manner. (Fensham, 2009; Finkelstein, 2005; Rennie and Parker, 1996; Vignouli, Hart and Fry, 2002; Waltner, Weisner and Rachel, 2007).

The Salters and Horners Advanced Physics programme in the United Kingdom is an examplar of such contextual teaching applied to physics. Developed at York University in 1996, the programme uses a variety of natural contexts, such as athletics (sans martial arts), to explore topics in classical mechanics. Students enrolled in the programme have reported that learning physics in this manner makes it more relevant and interesting to them, and follow-up studies reveal that they are more likely to continue their study of physics after the course has ended. In this case, the programme’s use of athletics – i.e., “Higher, Faster, Stronger” – demonstrates how sports can cover a wide array of physics topics. Using athletics as the mode of transmission, students of the Salters and Horners initiative are taught Newton’s laws of motion, energy and efficiency, springs, work and forces (2014).

In traditional classrooms—which is to say, those dependent on content-based teaching—physics lessons are structured so that related concepts are studied independently and separately. When learning about torque, for instance, students are not typically shown how the concept fits with the principle of waves, since that topic is reserved for another chapter. By contrast, in the contextual method, different aspects of the standard taught fare are communicated to the student simultaneously, since the goal is to integrate the material as a whole rather than to dissect the subject matter into its constituent parts. The actual teaching methods for both conventional and context-based learning are often quite similar, however. Yet in the latter, students are exposed to various “bits” from each conventional unit (what are typically broken down into achievement standards) as they progress through the academic year.
Several explanations have proposed to account for the improved outcomes in student performance and engagement in contextual science-teaching. In the real world, science (and physics) ideas are very rarely broken neatly into discrete experiential packages. Context-based teaching is ecologically valid in the sense that students are exposed to scientific concepts in a way that is consistent with how they encounter them in their everyday lives (Bennett and Hogarth, 2007).

Additionally, using real-world contexts as starting points in science teaching leads to students simply enjoying their science lessons more than they would in conventional courses, which has a cascade of positive effects (e.g., being more positively disposed towards studying science in the future) (Bennett and Hogarth, 2007).

Again, the context of sport has been used successfully, since it is inherently engaging, students tend to be familiar with it, and athletics incorporate many scientific ideas. The recent three-year project funded by Sport New Zealand (2014), which allowed participating schools to introduce context-based resources in physical education, maths and English, grew out of a growing body of data pointing to the benefits of sports in education. The project had several aims in mind, including the development of teaching and assessment resources in these subject areas by using sport as the central context to engage students in learning. Unfortunately, science took a back seat in that particular project, since literacy and numeracy were identified as core focus areas for student achievement by the Ministry of Education. Yet schools can use a similar model to introduce sport-based contexts for subjects other than maths and English. For example, in Dunedin, Queen’s High School, where I was teaching, was part of the Sport in Education project. During the 2014 Commonwealth Games, junior students used the Commonwealth Games as a pedagogical framework for learning activities across all subjects, including science.
One potential downside of adopting such an approach, however, is that students who are unfamiliar with the sport being used for the contextual teaching method may find it difficult to focus on the science, since their attention is divided between the novel subject matter and the rules and structure of a new competitive activity. Indeed, this problem of contextual “unfamiliarity” has been cited as a problem with contextual teaching in general (Korunsky, 2002). One must therefore be careful to ensure that students do not get focussed or lost in the context to the point that the science is only glossed over or missed altogether.

Overall, the research on context-based learning focusses on inspiring students in classrooms, treating the real-world context as only an ancillary teaching method to traditional learning strategies. A study on “amusement park physics” (Moll, 2010) is one of the few that involved actually taking the students outside of the classroom as the entire curriculum. Even that research, however, involved students who were already enrolled in a physics programme. Studies on individual differences in student learning styles, and how these may come into play in context-based science learning, in particular, are nonexistent. Young people who are completely disengaged or removed from the science classroom may be more strongly influenced by the teaching of science in context than their peers. From a basic societal perspective, this is a critical point, in that even less studious youth require a basic understanding of science to be able to make informed decisions on key community challenges, such as public health and environmental issues. Therefore, it may be useful to consider developing a far broader, even exclusive, context-based learning approach that treats it as more than simply a module or ancillary requirement of traditional classroom activities.
Experiment and Observation

Do Martial Arts Practitioners really understand Classical mechanics better than the general population? – Results of an online survey of a general population of adults

So far, we have seen that karate illustrates many core concepts in physics, especially those involving classical mechanics, as this is the physics of collisions, gravity, energy and the macroscopic world in general. The physics being taught in New Zealand secondary schools appears to dovetail with the practical applications taught to beginning practitioners of karate. It remains unclear, however, whether through their involvement in karate, these athletes acquire an implicit understanding of the physics principles explicitly taught in schools.

The case for using karate as a teaching method for classical mechanics would be strengthened if there were a known empirical relationship between the two. Literature searches yielded no such existing findings, however, and so it became apparent that I would first need to ascertain this presumed connection prior to any formal attempts to actually teach classical mechanics by using karate. Using an online testing method (SurveyMonkey), I therefore began by testing a range of people with differing degrees of familiarity with martial arts, exploring this hypothetical correlation between explicit martial arts knowledge and implicit understanding of classical mechanics. The questions used for this purpose are shown in Appendix 1.

As this was an initial exploratory study, the design was fairly informal and online recruitment proceeded largely by word of mouth and social media connections (e.g., Facebook posts, karate-course links). One hundred participants representing a wide range of martial arts competency—including those who had no experience whatsoever in the sport—completed the survey. Unfortunately, 45 surveys had to be disregarded because the participant answered less than half of the questions, including the critical question about their martial arts
background. All of the disregarded tests were participants who agreed to take part and then only answered the first one or two questions before exiting the test. In addition, only one participant self-identified as “training karate for one year or less”, so their score was not included in the results as it was thought to be too small a sample to show reasonable results. Finally, no participants selected the training karate for one to five years subgroup. In total, fifty four tests were completed and results collated with 52% of participants identifying as having never studied a martial art, 22% identifying as studying in the past, and 26% identifying as currently training and having at least five years’ experience (see Figure 1).

![Percentage of Participants in Each Group](image)

**Figure 1: Percentage breakdown of participants in each group**

To determine which types of questions to ask, copies of the Level 2 NCEA mechanics exams from the past two years (2012 and 2013) were obtained and the non-mathematical, concept questions were altered for use in the survey. The reason for not including the mathematical questions was that the intention was to assess the understanding of physics concepts, not mathematical skill. Indeed, up until 2012, the NCEA physics exams themselves were structured so that these two skills were assessed and marked independently of each other and
then the final marks combined to form the grade. In this way, it is recognised that the ability to perform mathematical calculations is a separate skill from applying physics knowledge.

Alternate questions on the same topics and at the same level but with a karate-specific context were used exclusively. This ensured that unfamiliarity with context of martial arts would not detrimentally affect results. The NCEA style examinations utilise a context in every examination. For example, the 2013 Mechanics exam consisted of questions solely concerned with the context of a circus. Using the questions in a karate context is consistent with NCEA practices. To ensure the validity of the questions that I was asking, prior to soliciting survey responses, the survey was vetted by another local Physics teacher to ensure that the questions adhered to two criteria. Criteria one ensured that they were pitched at the correct level which for the purposes of this study was level two of the New Zealand Physics Curriculum. This increased the probability that the level of difficulty of the questions had not been altered along with the context. Criteria two was that the questions were able to be answered by anyone with an understanding of classical mechanics at the level required for level 2 physics. In other words, the questions were written to be answered by anyone with a knowledge of physics as opposed to anyone with a knowledge of karate. It was important to ensure that content rather than context knowledge was being evaluated.

The final questions of the survey divided the participants into categories, those who had no martial arts experience, past practitioners of karate and current practitioners of karate (See figure 1). The current practitioner category was subdivided into those who had been training for one year or less, those who had been training between one and five years, and those who had been training for more than five years.

In NCEA marking, the N grade (Not Achieved) reflects the participant has either not attempted the question or attempted the question but is completely incorrect. The A grade
(Achieved) is assigned to participants who have partially correctly answered the question or correctly answered the question at a basic level without explanation. M or Merit grades are assigned to participants who have fully and correctly answered the question showing they understand the physics behind the question being asked. The E or Excellence grade is assigned when participants link concepts and fully explain ideas to show they have a mastery of the tested concept or idea. In addition, the questions in NCEA are also scored a number value between 1 and 8. For example an N grade can be N0, N1, or N2 depending on how close the participant was to the correct answer. At the other end of the scale, E7 or E8 distinguishes between higher levels of understanding.

For this test, the numerical grading scale was simplified to:

- 0 – no response – N grade
- 1 or 2 – N grade
- 3 – A grade
- 4 – M grade
- 5 – E grade

The exception to this grading was question one which was sufficiently lacking in complexity to warrant a score on a scale of one to five and so was graded on a scale of one to three (consistent with an N to A grading). This gave the overall possible score for the test forty eight points. Grading on a five point scale was done for ease of marking and because the entire experiment was designed only to test the hypothesis that martial arts practitioners had a better understanding of classical mechanics principals. To achieve this goal, it was not necessary to mark the questions as rigorously as one would mark a high school NCEA exam. As the final questions were those relating to the study of karate, the participant’s surveys were graded blind. The overall score was attributed to the test based on questions asked. Once an overall score had been determined, the participants’ group identity was revealed.
Until the survey was graded, the marker was unaware of which group the participant had self-identified with.

On average, participants in the never studied martial arts group performed worse than the other two groups on the physics questions. The participants who had studied a martial arts in the past did better than those who had never studied a martial art, and the participants who had been studying a martial art for more than five years scored the best results. The table below summarises the highest, lowest and average scores for each group out of a possible score of 48.

<table>
<thead>
<tr>
<th>Group</th>
<th>Highest Score</th>
<th>Lowest Score</th>
<th>Average Score</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never studied martial arts</td>
<td>33</td>
<td>9</td>
<td>17</td>
<td>5.2</td>
</tr>
<tr>
<td>(n=28)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Past study of martial arts</td>
<td>36</td>
<td>10</td>
<td>22</td>
<td>7.85</td>
</tr>
<tr>
<td>(n=12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current study more than 5 years</td>
<td>44</td>
<td>15</td>
<td>29</td>
<td>8.44</td>
</tr>
<tr>
<td>(n = 14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2: A table showing the number of participants in each group*

An analysis of variation (ANOVA) was completed to ensure the results were valid using an online ANOVA (http://www.physics.csbsju.edu/stats/anova.html) this returned a p value of 0.000. The assumptions of ANOVA were assessed and found to be met. The three experimental groups had similar distributions and a central mode (Figure 3).
The No Experience group had scores between a high of 33 and a low of 9 with an average of 17. In contrast, the scores of the group with past martial arts experience had higher scores, while the scores of the group that are currently training and have been for at least five years, the Expert Group, were higher again. The highest scorer in this group was 8 points above the highest scorer in the Past Experience group and thus 11 points higher than the highest scorer in the No Experience group. Likewise the lowest score was 5 points ahead of the lowest scorer in the Past Experience group and 6 points ahead of the lowest scorer in the No Experience group. The average score was 7 points higher than the average score of the Past Experience group and 12 points higher than the No Experience group.

![Frequency of scores plotted on Same Graph](image)

*Figure 3: Frequency of scores in each group with a curve fit to show the distribution of scores in each group.*

The graph with the curve on it shows that the distribution of scores for each group have shifted to the right in relation to their current knowledge of karate.

A suggestion for further research could be to investigate the people who had past experience of martial arts. In the survey, the participants were only asked if they had trained in the past. Further questioning could be done to determine if there is a correlation between the length of time that they have been away from training and their scores. In other words, for those who
had stopped training recently, do they tend to have higher scores than if they had stopped training ten years ago? Also, is there any correlation between the amount of time they trained in the past and how well they scored? Are those higher scorers in the previous participation group also the participants in that group who had trained longer overall?

The participants in the group that had been studying karate for more than five years had the highest average score (29 of a possible 48). There were significant differences between those who had undertaken study of karate and an understanding of classical mechanics principles (p < 0.0001). With those who have a greater experience of karate having a greater knowledge of classical mechanics.

Possible limitations in the design of the test included the fact that the participants were not asked what their level of familiarity with physics was. In other words, though it is highly unlikely, the group who answered that they had more than five years’ experience with karate may also have been more highly trained in physics. We can not rule this out. The only insurance that I have against this possibility is that the groups that I had posted the test link to contained no physics teachers yet were comprised of karate participants. We therefore can be reasonably certain that although I do not know whose survey was whose, I do know that the sample did not contain all physics teachers.

Generally the use of my own networks to distribute the test did help me to ensure that I was surveying a broad cross section. However, it could be argued that my social networks do not represent the general population. Therefore it would be beneficial in the future to retry the same experiment but recruiting a much larger sample size to ensure a group outside my social circle.

Related to this is the outside influence of factors such as geographic location, as my own social network groups are located mostly within two areas, New Zealand and North America.
Although this is good from the point of view that the people who answered the survey would have generally experienced a similar quality and level of education, it would be useful when revisiting the survey to include questions about geographical area to see if there is any cultural effect.

As the vast majority of respondents in the previous experience or currently practising categories had specific experience of karate, it would be interesting to recruit more broadly to see if there is a difference in intuitive understanding of physics between practitioners of karate and other martial arts.

Finally, in the original test design, the intention was to include a fourth group of people who had practised karate but for a shorter length of time. The lack of responses meant that there is no data available for students who have practised karate for less than five years. It would be interesting to involve more respondents and determine quantitatively how much participation in karate is required to see the increase in the knowledge of physics.

Based on the strong results from this study, subsequent work was undertaken to ascertain whether karate could be used as an effective context for learning. If, as the results suggest, the general population had shown that those who were undertaking regular martial arts training over a period of years had a better understanding of classical mechanics than those who weren’t, and those people had not been formally taught classical mechanics but rather picked it up as a side product of their martial arts training, then it would be possible to use teaching a martial art with a deliberate focus on classical mechanics to teach students.

**Is Karate an effective method of teaching Classical Mechanics in Secondary School?** – A pilot study using Level 3 Achievement Standard 3.2 Demonstrate understanding of the application of physics to a selected context
In 2013 and again in 2014, I undertook two small pilot studies with groups of students at Level 3 of the physics curriculum. These students had been exposed the previous year to introductory classical mechanics concepts in their study of Level 2. The purpose of the pilot studies was to judge whether students believed this would be a method of learning that they would enjoy and also whether or not it was possible to explicitly transmit concepts while trying to teach karate.

In 2013, for a period of two weeks (eight sessions in total), my small physics class of thirteen female students participated in an introductory karate course that was designed to teach them classical mechanical concepts such as force, energy, Impulse, momentum, torque and circular motion. At the end of this period, the students were asked to produce a piece of written work or a video outlining what they had learned about the relationship between karate and physics. They also filled out a questionnaire in which they were asked to give feedback on their personal experiences with this alternative unit, a unit which was obviously a departure from that of the standard classroom environment.

As this was a very small sample group intended as a pilot study – there were no quantitative findings that could be taken from the survey. All that was desired was a general feel for how the students themselves perceived the idea to work with like-minded peers.

The work received back from this unit was of a reasonable standard and consistent with work they had been handing in based on classroom based learning. The students who did hand in work unanimously at least passed the level required for NCEA level 3 credits. The only students who did not achieve at even the most basic NCEA level were those students who did not hand in work. These tended to be the students with a history of missing assignments and was not out of character. Similarly, there was a group of students who produced outstanding work. Again, this was consistent with their classroom performance. This suggests that taking
the students out of the classroom for their learning did not negatively impact their general performance on the assessment task.

The feedback obtained was overwhelmingly positive, with all of the students saying that they enjoyed the unit. The students’ responses to the survey indicated that they most enjoyed the application of the physics that they had been learning in the classroom to a real-world scenario. All of the students responded that they believed the program would be an effective way of communicating level two mechanics principles to other students, *even if those students had never studied mechanics*. One student included the qualifier “more explanation of the physics might be needed” but that individual still agreed that the program would be effective.

It is interesting to note that I had not planned on running any study with students at this level beyond 2013. However, my incoming class in 2014 had heard about the karate unit from the class above them and requested to do the same. For this group, I ran the class slightly differently by cutting down the number of sessions that the students had outside the classroom and making them more intensely physics focussed. I tried very hard in 2014 to make the physics more important than the karate, where as in 2013 I had been emphasising them equally. I also reworked the accompanying handbook to the unit to reflect renewed focus on the physics.

The results from the 2014 class were even better than the previous class. I had a higher percentage of students handing in work and the work was of a better standard than the previous year. The students in the 2014 group were linking concepts together and showing an in depth knowledge that had not been present in the class of 2013. For example, where in the 2013 cohort, the best students were linking together related concepts, the best students in the 2014 cohort went a step further and supported this conceptual linking with numerical
examples using measurements from their own bodies and experiences. Once again the students responded very positively to the unit, including one student who is wheelchair bound but still found that she was able to participate in most of the activities.

**Is karate an effective context for teaching Level 2 Classical mechanics to the general public? - Using karate to teach Classical Mechanics to intermediate age students at the International Science Festival.**

In 2014, I was asked to develop and deliver a series of workshops targeted at the general public as part of the New Zealand International Science Festival held in Dunedin. I thought this would be an ideal opportunity to investigate whether or not my ideas that karate would be an effective way of teaching classical mechanics to the general public. This was based on the results from the testing of the general public as well as the positive results gained in my own classroom with my physics students.

The challenge with the Science Festival workshops was to pitch the workshops so that they would be accessible to the general public. I had no idea what the background experience of the people that came to the workshops would be so it was necessary to pitch the accompanying workshop material at an introductory level but also to include supplementary material for those who might already have prior knowledge.

As a high school teacher and having experience teaching karate to children, I asked that that workshops be limited to participants over the age of 8 years old with no upper age limit restriction. I selected this age restriction to keep in mind the downfalls with context based learning. I have found that in karate classes, students who are under the age of about 8 have a hard time controlling their movement. I felt that, if I included younger participants, there was a danger that they would be so focussed on controlling their movements that they would miss the physics instruction. I felt that the physical development of the younger students might
mean that they would spend so much time concentrating on moving that they would not pick up the physics behind the movements they were undertaking. This focus on the context rather than the material being transmitted via the context is an identified concern when designing a context based learning experience (Korunsky, 2002).

In the end, I found that my participants were generally between 8 and 14 years old with only a handful of participants in each workshop who were older (adult) or younger. I decided in consultation with the Science Festival organisers to limit the participant number to 15 because of logistics and safety of having large numbers of karate beginners with only myself as instructor and two of my own students to help out. I also worried that I would not be able to give them as much individual instruction in a larger group. In the end, however, the workshops were oversubscribed with one workshop having 22 participants and the other two workshops having 20 participants.

The participants in the workshops, like those in the survey of physics knowledge in the general population, were both male and female. Each of the workshops were balanced with male and female participants. Interestingly, there were many workshops with brother sister or other sibling pairings. One of the comments that came from the feedback solicited after the workshop was “I liked getting to work with my sister”. This could be another advantage of this approach, as participants were not segregated by age, they could experience learning together with a partner whom they felt comfortable and safe with, in this case a sibling.

I chose the material for the workshop based on lessons that I felt had been successful with the secondary school students and also could be easily modified to suit a more general public audience. I tried to avoid any concepts which required a large degree of background knowledge other than what was observable in everyday life. I also tried to ensure that, as I was anticipating children as an audience, the karate that I was going to teach was safe and
easily accessible to a beginner. The only session that I was worried about in terms of safety was the last workshop of the series, which was a session on throws and takedowns. As a result of this concern, I practised with a children’s class of karate students in advance. The children in this karate class were in the same 8-14 year old age group I was targeting with the science festival sessions. It is an interesting effect to note that the students in that class still use physics terms like “centre of mass” and “base of support” when describing throws and takedowns despite it having been months since I taught them that lesson. It would be an interesting project in the future to survey these students and the participants in the Science Festival workshops to see if they had retained physics knowledge from the karate lessons over time.

The workshops were one hour in duration and participants were told to arrive in loose, comfortable clothing. Workshops were held at the Dunedin Public Library in an empty room. During the hour workshop, we did a warm up and then progressed into learning techniques where, like with the girls in the physics classes, I was very careful to explain the physics behind each movement as we went along. For example in the first session when we were talking about the different stances in karate, I incorporated the centre of mass and balance ideas with a series of small experiments that the participants undertook with a partner. They tried out different stances and foot positioning with their partner to see which ones gave the most stable feeling to them. At that stage we then talked about centre of mass and where their centre of mass was in comparison with their feet in both stable and unstable stances. This is also analogous to the instructor that I saw in Okinawa and the way that he instructed students to find the best positions in stances for their body.

At the start of sessions two and three, I also did a quick recap of the principles we had studied previously and the techniques that demonstrated those principles as we had a mixture of returning and new participants to each workshop. The main emphasis of the session was
learning the techniques that would demonstrate the concepts I was trying to cover in the session. At the end of each session, I had the students explain to me verbally what they had learned.

The Appendix shows the print materials that were developed to accompany the workshop series. It is important to notice that they are different than the materials that were developed to target the secondary school physics students although the material covered is essentially the same. The main difference was in the language used. For the children I tried to cover the concepts using simpler language and examples of things that a child would observe. I also used many more illustrations and colourful pictures for the children’s version than the secondary school student version. Perhaps this was because I was aware that although my secondary school students are undertaking this unit as serious school study, the children were voluntarily coming to what, to them I felt, was a fun workshop and so the workshop materials should also reflect those differing purposes.

After each session, I surveyed the participants. As I was aware in advance of the possibility of the majority of participants being children, I asked the participants to circle happy faces to sad faces on a scale corresponding to a 1-5 ranking as shown.

<table>
<thead>
<tr>
<th>NO!!!</th>
<th>not really</th>
<th>Don’t know</th>
<th>it was ok</th>
<th>YES!!!</th>
</tr>
</thead>
<tbody>
<tr>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😞</td>
<td>😊</td>
</tr>
</tbody>
</table>

The survey questions for each workshop were the same and are as follows:

- I enjoyed the workshop
- I would come to another workshop
- I would recommend this workshop to my friends
Combined results from the series of three workshops are as follows:

**Figure 4:** Science Festival Workshop participant’s responses to the question “I enjoyed the workshop”

![Pie chart showing 98% enjoyment of the workshop](image)

**Figure 5:** Science Festival Workshop participant’s responses to the question “I would come to another workshop”

![Pie chart showing 90% interest in another workshop](image)
Figure 6: Science Festival Workshop participant’s responses to the question “I would recommend this workshop to my friends”

Although this was by no means a rigorous scientific study but more a means of acquiring informal feedback, I believe it speaks strongly to the novel nature of the workshops. The participants enjoyed the format of the workshops and most would come back. It is interesting to note that as a comment to question number three, “I would recommend this workshop to my friends”, one of the participants commented “I wouldn’t recommend only because I would probably forget”. All the results must be viewed in the context that the respondents were primarily children.

The participants at the Science Festival surprised me with their grasp of the physics concepts I was trying to impart through the karate. One child explained to me the relationship between momentum and impulse as it related to a punching technique in a way that I would have been happy to have heard my level 2 Physics students explain it. Many of the child participants were using physics terms and concepts to form explanations for techniques that far surpassed the level of physics knowledge I would have expected from students at their age and level. I
believe that this is a further example of how the context of karate can work in making the concepts of classical mechanics more accessible to everyone, not just students of physics.

**Suggestion for Further Research: Is karate an effective context for teaching level 2 classical mechanics to female high school students? – Outline of a future study using female secondary school students not currently engaged in Physics study.**

In the New Zealand Curriculum – the study of science is compulsory until Year 10. This is the second year of high school. In Year 11 which is the first year of NCEA, schools have many options on how to build their courses to suit the needs of students. As a result, the science knowledge of a given set of students can vary dramatically in both content and depth. Engaging and teaching students who have disengaged from formal study of Science at this early exit point is a focus of the next study.

Building on the results found in both the pilot study, the testing of the general public and the work at the Science Festival, it was hypothesised that karate could be used as an effective context for teaching Level 2 classical mechanics to secondary school aged students. If the students were to respond positively to learning classical mechanics outside the classroom in a purely contextual way, then it is hypothesised that this could be a way to engage more girls in the physics classroom, particularly those who have become disengaged from the classroom process.

In this experiment, it is necessary to control the students for age and gender to ensure that these are not factors that were influencing the relationship seen in the testing work with the general public. Hypothetically, select students at a local all-girls high school. The students would complete learning in physics in the gym, away from the physics classroom. None of the participants would be part of a physics class.
The students should be pretested using a Solomon four group approach. At many schools, there is a top stream class and a cohort of more than one mixed ability classes. Students are generally assigned to classes at random with care taken to avoid obvious problems such as having all students with a history of problem behaviour together. Mixed ability classes should be chosen rather than higher or lower identified cohorts so as not to skew the results in either direction. Two classes should be identified and chosen by the school so the experimenter has no influence in the subjects included in the classes and no knowledge of the classes as a group. One class should be further subdivided into two groups. One group to be pre and post tested to determine the effect of the learning on their physics knowledge. The second sub group to be post tested only to ensure that the pre-test was not an influence on the results. The students should be randomly assigned to the sub groups. This can be done by the school or by using a roll of student numbers to avoid identification of the subjects to the experimenter in advance. A second class is used as a control group, again identified by the school to be similar in age, ethnic mix and ability level to the students who are subjected to the physics learning. The use of a control group is to ensure that any effects observed are due to the contextual learning in karate classes and not due to any outside factors. The control group should be further subdivided randomly into students who are pre and post tested and students who are post tested only.

An experiment of this nature is low impact to the students and the teacher in the class. The students in the control group are not impacted in any way other than the taking of the pre and post testing. This can be designed so that it can be used by their classroom teachers as a benchmark of their prior learning in physics so is not an exercise that is of no value to the students themselves or their learning. The students in the intervention group are given the intervention during their regular class work. The classroom teacher can use the student journals and reflection as a way of tracking their progress and learning during the exercise. If
junior school students are used for this experiment then their learning should be enhanced rather than detrimentally affected by taking part in the experiment.

This experiment and others suggested in this thesis are ones that I am eager to undertake but are beyond the scope of the present work.
General Conclusions and Discussion

It is intriguing to consider that, despite the historical lack of “lecture-based” classes in the martial arts, the sport has proliferated and grown extensively over the centuries. This is true not only of the practice martial arts in general, but also lineal knowledge. My conjecture in this thesis is that the success of karate is based largely on the fact that teaching martial arts centres on the relationship between student and expert, and this relationship aids in transmitting the information necessary for the student to attain mastery of the concepts imparted. The idea of relationship-based teaching may also prove successful in helping to (re)engage science students. This is particularly true for girls, since supportive relationships with teachers have been shown to have a significant impact on the female learning outcomes.

To justify further research, my first study attempted to answer the question of whether people skilled in karate posses a better understanding of classical mechanics than the general population. If there were a difference between the classical mechanics knowledge of the general population and those practising martial arts, and these people are not practising martial arts with the specific aim of learning physics, then the sport is likely an effective tool for teaching classical mechanics.

As predicted, my initial survey results showed that individuals who practised karate indeed had an intuitive understanding of the physics principles constituting the curriculum at secondary schools in New Zealand. Given this correlation, the use of karate as a context for teaching classical mechanics principles was given credence. Since current research shows a lack of engagement in students (especially girls) when it comes to studying physics, the notion that educators can use martial arts, especially karate, to inspire students who have become disenchanted with traditional classroom learning was a promising one.
Based on the success of this initial work, several further pilot projects were undertaken with adolescent females to determine if karate works as a pedagogical framework in which to teach physics to teenage girls, a demographic that, again, has been identified in the literature as being at high risk of science disengagement.

Additionally, I designed and ran a series of workshops at the New Zealand International Science Festival (titled, “Fight Like a Physicist”). This involved surveying and quizzing students at three in an effort to gauge their physics knowledge before and after their participation in the martial arts exercises. Due to the time restrictions and nature of these public venues, I made sure that the workshops were clearly physics focussed and that the karate served as a delivery method, rather than featured as the main event. Therefore, I did not get caught up in karate technique or the subtly of certain movements in the sport, but instead focused on communicating the bigger picture. The workshops were successful in teaching the students physics concepts. An additional effect I did not forsee was the application of the knowledge to different situations. For example, when we were talking about safety equipment and gloves that “crumple”, a boy asked about whether this was similar to crumple zones in cars. In general, the students were very positive and able to accurately reflect the learning goals orally at the end of the workshop.

In addition to the workshops, I also presented my argument for karate-based physics teaching at the 2013 New Zealand Institute of Physics biennial conference, incorporating feedback and discussions with my highschool students. The idea was well-received by the physics teaching community. Upon sending my students’ work to Wellington for moderation in 2013, the examiner’s report summarized that the context of karate was a novel one and that the idea was sound. (There were, however, helpful suggestions for improvement to the content, which is reflected in changes between the 2013 and 2014 versions in the Appendix).
Ideally, follow-up research will include controlled experiments (such as the one I have outlined in the previous section) to test the present hypotheses more carefully. It is an area deserving of further empirical investigation, especially given the unfortunate and ongoing trend of girls opting out of physics courses at the senior secondary level. By contrast, whatever cultural influences once impeded female involvement in traditional martial arts have largely subsided, and support for girls in the sport has never been stronger. More females are participating in karate than ever before. Ideally, further studies in the field of context-based learning will build on the present exploratory project, continuing to cultivate what appears to be an especially fruitful marriage between martial arts and physics.
References


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- [http://saltersinstitute.co.uk/course-the-salters-horners-advanced-physics/](http://saltersinstitute.co.uk/course-the-salters-horners-advanced-physics/)
- [http://www.wkf.net](http://www.wkf.net)
- [http://www.york.ac.uk/org/seg/salters/physics/](http://www.york.ac.uk/org/seg/salters/physics/)
Appendices – Online Test Questions and Creative materials in Support of Learning
Appendix 1 – Online Test Questions from Comparison testing of Martial Arts vs non-Martial Arts practitioners

**Equilibrium**
Explain why it is better to keep your feet hip width apart rather than one directly behind the other.

**Momentum and Impulse**
There are two aspects to a more effective technique which will result in your techniques having more momentum. What are they?

In competitions, during the kumite rounds, competitors use gloves as well as shin and instep protectors. One reason for this is to protect their opponent. Explain why striking someone with an ungloved fist would be more damaging than a gloved fist even if the strike used the same amount of force.

One person runs towards and collides with a much smaller opponent who is standing still. Explain what you think would happen to the position and velocity of the two competitors after they collide.

**Friction and other Forces**
The following quote is from a website that manufactures mats for martial arts.

---

*Resilite offers two thicknesses: RSP600 1” or RSP625 1-1/4”. For martial arts that involve fast foot movements (such as Tai Kwon Do and Kung Fu) we suggest using our RSP600 1” thick MMA mats. This martial arts mat provides good impact resilience while being slightly firmer than our 1.25” mat.*

*For Submission Wrestling, Brazilian Jiu Jitsu, Grappling, or Combative Training we suggest using our RSP625 1-1/4” thick MMA mats. This mat provides additional impact protection but has a slightly softer feel.*

---

Explain why, in terms of friction, a firmer mat is better for martial arts that involve fast foot movements.
Hooke’s Law and Springs
In hoju undo, students use a variety of different training aids to help them develop and strengthen their muscles. Two competitors are using the equipment shown below to work on their upper body strength.

One person is using the equipment as shown while the other has removed two of the springs from between the handles. Explain which person has the harder workout and how you decided.

**Force components**
Striking someone to the shoulder or head, more force is felt if the blow is struck vertically downwards rather than at an angle as shown. Why is this?

**Vector addition of Forces**
If you were trying to maximise the impact of your technique, why would it be better to pull your opponent towards you while punching them rather than just punching them?

**Energy**
Which opponent has more potential energy if they both fall on you with their full bodyweight from the same height, the one with more mass or the one with less mass? Why?

**Acceleration and Velocity**
If I run around the mat at a constant speed, I am accelerating but if I run across the mat at a constant speed I am not accelerating. Explain why.
Appendix 2 – 2013 Iteration of a workbook created for Level 3 Physics students in a Physics of Karate unit.

All students were issued a plastic covered spiral bound version of the booklet to write their own notes in and use throughout the unit for reference.
Physics 3.2 – Fight like a physicist

Name: ____________________
**Introduction**

This booklet covers what you will need to know to pass Physics 3.2 “Demonstrate an Understanding of the Application of Physics to a Selected Context”. For this assessment you will be demonstrating your understanding of Physics to the selected context of Karate and demonstrate how physics will make you a lean, mean, fighting machine.

You will have 8 class periods of instruction to complete this unit of work. At the end of the unit you will be assessed both practically and through the presentation medium of your choice. The practical component of your exam may be recorded in accordance with NCEA moderation requirements.

What do you need to do to Achieve (and beyond) in this unit?

- Attend classes with a smile
- Attend make up classes if necessary
- Attempt all that is asked of you to the best of your ability
- Use your amazing powers of physics only for good, never evil
Lessons 1: Patience, Grasshopper

Before we delve into the exciting world of glitz and glamour that is karate for physicists, we need to see what we know, or what we don’t know. We are going to start with a written test. This is because we are taking the classroom theory to the practical. So let’s take our mechanics theories from last year and put them in a karate context. Then when we start the practical lessons, we have some theory to think about already.

Please answer the following questions in your book using blue or black pen only.

Equilibrium

Explain why it is better to position yourself low and balanced on both feet equally rather than putting more weight on one foot?

Explain why it is better to keep your feet hip width apart rather than one directly behind the other.

Momentum and Impulse

There are two aspects to a more effective technique which will result in your techniques having more momentum. What are they?

In competitions, during the kumite rounds, competitors use gloves as well as shin and instep protectors. One reason for this is to protect their opponent. Explain why striking someone with an ungloved fist would be more damaging than a gloved fist even if the strike used the same amount of force.
One person runs towards and collides with an opponent who is standing still. Explain what you think would happen to the position and velocity of the two competitors after they collide.

**Friction and other Forces**

The following quote is from a website that manufactures mats for martial arts.

Resilite offers two thicknesses: RSP600 1" or RSP625 1 1/4".

For martial arts that involve fast foot movements (such as Tai Kwon Do and Kung Fu) we suggest using our RSP600 1" thick MMA mats. This martial arts mat provides good impact resilience while being slightly firmer than our 1.25" mat.

For Submission Wrestling, Brazilian Jiu Jitsu, Grappling, or Combative Training we suggest using our RSP625 1 1/4" thick MMA mats. This mat provides additional impact protection but has a slightly softer feel.

Explain why, in terms of friction, a firmer mat is better for martial arts that involve fast foot movements.

Explain why, in terms of Impulse and momentum, why a softer mat is better for impact protection.
Hooke’s Law and Springs

In hoju undo, students use a variety of different training aids to help them develop and strengthen their muscles. Two competitors are using the equipment shown below to work on their upper body strength.

One person is using the equipment as shown while the other has removed two of the springs from between the handles. Explain which person has the harder workout and how you decided.

Force components

Striking someone to the shoulder or head, more force is felt if the blow is struck vertically downwards rather than at an angle as shown. Why is this?
**Torque**

Jane is trying to flip her opponent who is much larger. Explain why it is better for her to apply her pushing force further from his centre of mass by pushing on his arm rather than pushing the middle of his body at the same height.

Why is this:更好 than this？

**Vector addition of Forces**

If you were trying to maximise the impact of your technique, why would it be better to pull your opponent towards you while punching them rather than just punching them?

**Kinetic Energy**

Why is it important that techniques be as fast as possible?

**Potential Energy**

Which opponent has more potential energy if they both fall on you with their full bodyweight from the same height, the one with more mass or the one with less mass? Why?
Acceleration and Velocity

If I run around the mat at a constant speed, I am accelerating but if I run across the mat at a constant speed I am not accelerating. Explain why.

Very good – you have finished the pre test!!
Lesson 1 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lessons 2-3: A Journey of a Thousand Miles Begins with a Single Step

Physics Focus: Forces, Centre of Mass and Momentum

The basics – These two lessons are an introduction to karate. Try hard to think of how Physics is integrated into the things that you are learning.

Class format

Every class will be composed of the same parts.

- Junbi undo – preparation exercises and warm up
- Kihon – basic movements and techniques
- Kata – prearranged forms – these are patterns that help you remember the kihon and show your understanding of techniques
- Kumiite – sparring

There are other components, however, this is what we will be focussing on for this unit.

Language

Usually, Japanese is used for counting, technique names, and instructions. Here is a guide to help you with some of the Japanese you might hear.

<table>
<thead>
<tr>
<th>General Commands</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Onegai shimasu</td>
<td>Please teach me</td>
</tr>
<tr>
<td>Shugo</td>
<td>Line up</td>
</tr>
<tr>
<td>Kiyotsuke</td>
<td>Stand (At attention)</td>
</tr>
<tr>
<td>Rei</td>
<td>Bow</td>
</tr>
<tr>
<td>Hajime</td>
<td>Start</td>
</tr>
<tr>
<td>Yame</td>
<td>Stop</td>
</tr>
<tr>
<td>Arigato gozaimashita</td>
<td>Thank you</td>
</tr>
<tr>
<td>Hai</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Counting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ichi</td>
</tr>
<tr>
<td>Ni</td>
</tr>
<tr>
<td>San</td>
</tr>
<tr>
<td>Shi</td>
</tr>
<tr>
<td>Go</td>
</tr>
<tr>
<td>Roku</td>
</tr>
<tr>
<td>Shichi</td>
</tr>
<tr>
<td>Hachi</td>
</tr>
<tr>
<td>Kyu</td>
</tr>
<tr>
<td>Ju</td>
</tr>
<tr>
<td>Stances</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Heisoku Dachi</td>
</tr>
<tr>
<td>Musubi Dachi</td>
</tr>
<tr>
<td>Heiko Dachi</td>
</tr>
<tr>
<td>Shiko Dachi</td>
</tr>
<tr>
<td>Zenkutsu Dachi</td>
</tr>
<tr>
<td>Neko Ashi Dachi</td>
</tr>
<tr>
<td>Hachiji Dachi</td>
</tr>
<tr>
<td>Sagi Ashi Dachi</td>
</tr>
<tr>
<td>Sanchin Dachi</td>
</tr>
<tr>
<td>Benzoku Dachi</td>
</tr>
<tr>
<td>Kokutso Dachi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Striking Techniques</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyaku Zuki</td>
<td>Reverse punch</td>
</tr>
<tr>
<td>Kizami Zuki</td>
<td>Jab</td>
</tr>
<tr>
<td>Oi Zuki</td>
<td>Lunge punch</td>
</tr>
<tr>
<td>Nukite Zuki</td>
<td>Spear hand strike</td>
</tr>
<tr>
<td>Mae geri</td>
<td>Front kick</td>
</tr>
<tr>
<td>Mawahí Geri</td>
<td>Roundhouse kick</td>
</tr>
<tr>
<td>Age uke</td>
<td>Rising block</td>
</tr>
<tr>
<td>Chudan uke</td>
<td>Middle block</td>
</tr>
<tr>
<td>Gedan uke</td>
<td>Lower block</td>
</tr>
</tbody>
</table>
Kihon (The Basics)

The following are some pictures to help you remember what you have learned in lessons 2 and 3.

<table>
<thead>
<tr>
<th>Stances</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heisoku Dachi</td>
<td>Toes and heels touching</td>
</tr>
<tr>
<td>Musubi Dachi</td>
<td>Heels touching</td>
</tr>
<tr>
<td>Heiko Dachi</td>
<td>Parallel Stance</td>
</tr>
<tr>
<td>Shiko Dachi</td>
<td>Table Stance</td>
</tr>
<tr>
<td>Zenkutsu Dachi</td>
<td>Forward Leaning stance</td>
</tr>
<tr>
<td>Neko Ashi Dachi</td>
<td>Cat Stance</td>
</tr>
<tr>
<td>Hachiji Dachi</td>
<td>Natural Stance</td>
</tr>
<tr>
<td>Segi Ashi Dachi</td>
<td>Crane Stance</td>
</tr>
<tr>
<td>Sanchin Dachi</td>
<td>Hourglass stance</td>
</tr>
<tr>
<td>Benzoku Dachi</td>
<td>Crossed stance</td>
</tr>
<tr>
<td>Kokutso Dachi</td>
<td>Back leaning stance</td>
</tr>
<tr>
<td>Striking Techniques</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Gyaku Zuki</td>
<td>Reverse punch</td>
</tr>
<tr>
<td>Kizami Zuki</td>
<td>Jab</td>
</tr>
<tr>
<td>Gi Zuki</td>
<td>Lunge punch</td>
</tr>
<tr>
<td>Nukite Zuki</td>
<td>Spear hand strike</td>
</tr>
<tr>
<td>Mae geri</td>
<td>Front kick</td>
</tr>
<tr>
<td>Mawashi Geri</td>
<td>Roundhouse kick</td>
</tr>
<tr>
<td>Age uke</td>
<td>Rising block</td>
</tr>
<tr>
<td>Chudan uke</td>
<td>Middle block</td>
</tr>
<tr>
<td>Gedan uke</td>
<td>Lower block</td>
</tr>
</tbody>
</table>

**Parts of the body:**

- **Jodan**: upper area / head / neck
- **Chudan**: middle / shoulders to belt
- **Gedan**: lower / below belt.
Lesson 2 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lesson 3 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lessons 4 and 5: Pop it, Lock it, Polka-Dot it

Physics Focus: Forces and Torques

In this class we are looking at locking techniques or joint techniques. In the basics classes we focussed on techniques that relied on force, momentum, Impulse and linear kinematics principles. In the application of locks, we are looking at torques.

Locks are important tools for torque for two reasons. They allow you to more easily move someone about their centre of mass using their own arms or hands to create a distance from the pivot point of rotation. Also because we are dealing with bones and joints, the bones and joints of your body will respond when they are subjected to a torque in a way that will cause them to “Lock”

Locks that you should learn, know and love:

1. Wrist lock
2. Elbow lock
3. Shoulder lock

Theory:
Torque is the ability to start rotation around some pivot point. You can think of torque as rotational force. A rotational force will cause a rotational push and hence generate a rotational acceleration. If you think about something as simple as a drink can. The top operates on torque. Have you ever tried to open a drink and had the tab pop off? So annoying because it is hard to open the can without the tab, you can’t exert enough torque to open it. But put that same force to work at a distance from the pivot point by using the tab and it is easy to open a drink. Torque is a force with a distance from the pivot point.

Torque = Force x distance

This concept is applied against an opponent. If you wanted to rotate your opponent, you would not push on the centre of his chest because there is no distance from your applied force to his rotational centre of mass. You would push against the edge of his shoulder to cause him to rotate around his centre of mass. For even greater leverage, you could apply your force at his arm, say at the elbow. This is where the locks come in. Besides being uncomfortable to the opponent, a lock provides a way for you to make sure you have a solid hold at a distance from the pivot point which will allow you to easily move the opponent.

Another application of torque to a lock is in the actual lock itself. Because our joints are made of bones, the application of a torque will cause the joint to lock. Further application of the torque past the locking phase will cause bones to break. In this way, the application of a torque force can be a very effective technique.
Lesson 4 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lesson 5– Self Reflection

What did I learn today?

Questions that I have for next class?
Lessons 6 and 7: The Throwdown Showdown

Physics Focus: Circular Motion, Acceleration and Gravity

Theory: Gravity is our friend in Karate. Mostly because gravity helps us take people down. Gravity is always pulling down on our centre of mass and so, by shifting the centre of mass, we can make an opponent fall. Once on the ground, the opponent is weaker than when they are attacking you from a standing position.

Acceleration due to gravity is $9.81\text{ms}^{-2}$. Even just falling your head is going to experience a significant force, and, if we can lessen the time of impact, we can make falling a fairly painful event. Applying enough force to encourage your opponent to free fall under gravity is the main aim of the takedown.

When we are undertaking the lessons in takedowns, we will be using the gym mats to ensure safety. This is because of our old friends momentum and Impulse. Hit the unyielding gym floor from standing and the time of impact is very fast so the force you feel is very hard. Because you have the same momentum falling on a soft mat, and $p = F\Delta t$, falling on a soft mat increases the time of impact and so you feel less force.

How else can you make it hurt less? Break fall. There are a few things with the breakfall technique that you will learn but essentially there are two goals – 1. Spread the force of the fall out as much area of your body as possible and 2. Take the force on the “nonessential” parts of your body (arms and legs rather than neck and head).

We will also look at some circular motion takedowns. These are physically interesting because they make use of the principles of circular motion. You will try to turn as small a circle as possible causing your opponent to trace a large circle. This will cause them to accelerate and so they will fall down.
Lesson 6 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lesson 7 – Self Reflection

What did I learn today?

Questions that I have for next class?
Lesson 8: I Came, I Saw, I Got Punched in the Face

*Physics Focus: Mechanics Principles that you have learned*

Over the last few lessons, you have become a lean, mean, physics fighting machine. This is your chance to show the world what you have learned.

First, you need to find a red or other coloured pen. Go back and re take your Lesson One test, correcting any mistakes in the new colour. DO NOT REMOVE ANY PREVIOUS ANSWERS. You can add, change or annotate but make sure you previous answer is still readable.

Second, you have learned much in a short time, grasshopper. Now you must show it off. You and a partner will need to come up with a kata that will demonstrate your knowledge of Karate Physics to the world (ok, just the class). **You need to come up with a series of movements of no less than 30 seconds and no more than 2 minutes in length.**

Points to follow:
- You will need to remember the sequence and be able to perform it the same way every single time you do it.
- You will need to think about movements and stances as you go through the routine.
- Your routine can contain any movements that you have learned but must begin and end as you have been taught
- You need to fill in the following pages and explain the movement you chose and the physics principles involved. An example has been done for you.
EXAMPLE: Physics Dai Ms Hall

Begun with bow than move to yoi:

First move: step to left with left foot unto Han zentu su Dachi, Hiki uchi left hand
Gyaku zuki right hand.

End position 1:

strike is effective because mass is fast strike
kiss makes it easier
kiss makes small

knees are bent to lower center of mass
which will improve balance

Second move: step forward, rising block with left hand.

Third move: Gyaku chudachi to turn 180°

It is important to stay low
because this will lower
my center of gravity making
it harder for an opponent
to push me over.

Note that it is not necessary to make a detailed explanation for every movement BUT in your kata plan I would like to see at least 5 physics ideas explained.
Appendix 3 – 2014 Iteration of a workbook created for Level 3 Physics students in a Physics of Karate unit (includes Teacher’s Guide).

The differences in the 2014 version of the print material are subtle, however, the class structure as outlined indicates the difference in the teaching method used for the 2014 class. The suggestion that students are at risk of becoming so focussed on the context that they miss the intention of the lesson is a real problem (Korsunsky, 2002). I observed this in a minor way with the 2013 class. I think that I was too focussed on their technique and gave equal weight to learning karate and learning Physics. In 2014, the lessons were much more focussed on Physics. The technique I did not worry about unless it was going to compromise the safety of the activity. As a result, the 2014 students had much better results in terms of their submitted work. The end goal is important, when learning in the context of an unfamiliar sport, the students need to be reassured and encouraged not to get bogged down in the rules of the sport and instead look at the Physics of their motion as they attempt to perform movements in different ways.

In an attempt to make the material more accessible, I also added a teacher’s guide (preceding the student workbook) with instructions on lessons and examples of activities that could be used in each lesson.
Physics 3.2 – Fight like a physicist

Teacher’s Guide
**Introduction**

This booklet contains supplemental material for teaching the standard Physics 3.2 “Demonstrate an Understanding of the Application of Physics to a Selected Context” using the context of karate. The student notes are included alongside a guide for running the activities for the students and points on what to look for in the practical sessions.

For the sessions, the students will need to be taken to the gym, hall or other room that is free of furniture and other hazards that would impede student movement. Students should also be instructed to wear comfortable clothing (or PE uniform). Shoes and socks need to be removed. Any jewellery should also be removed, particularly watches, bracelets, rings and necklaces as during partner work they may catch the partner’s hands, fingers, toes etc and cause injury.

The unit of work is intended to take 8 practical sessions to complete with additional time given for the students to research and write up their assessment as necessary. It is recommended that at the end of the unit, students will be assessed both practically and through the presentation medium of your choice. The practical component of their assessment may be recorded in accordance with NCEA moderation requirements.

Because I ran a karate class for students as an extra curricular activity after school, if a student missed a class of practical activity then I would recommend that they attend an afterschool class as a makeup session. Additionally, I ran a makeup session during a “25th hour” class where students had a free period for any students who had not completed all the practical classes. It is recommended that there is some method of catching up students who miss a practical activity.

The lessons are made up of a practical activity and time for reflection. It is necessary to be specific and guide the students in their reflection, especially if this is new to them. Also ensuring that the students have time to write reflection at the end of the lesson is essential to the quality of the work handed in. The students should be told that their book will be used as part of their assessment as well as referred to by them back in the classroom and so they need to make sure their reflection captures the Physics that they learned in the session.

Partner work is essential in karate because you will never be working alone, techniques are all meant to be applied to an opponent and it is important to practise as such. Additionally, people are all different, big, small, short, tall – techniques that are easily applied against one particular type are not easily applied to another person. For this reason, I always make the students practise with different partners and we do a practical activity multiple times with a different partner each time.

Each lesson for the students is printed below with teacher instructions and notes in italics.

**Important Note:** The lessons are hands on and practical. The sessions involve the students working with each other on techniques that have the potential to harm or cause injury. Before every lesson I reiterate with the students that they need to be kind to each other and be good partners. They also need to know “tap out” and immediately release and step away if their partner taps out. They are to move slowly when doing holds so they don’t injure their partner before the partner has
It is vital that the teacher or person leading the practical sessions feels that they have the skills needed to guide the students and keep them from injuring themselves and each other. I also recommend that demonstrations are done with every technique before the students are allowed to commence. For example, for takedowns and breakfalling, I will takedown every student and make sure they are able to breakfall safely before letting them loose on each other.
Lesson 1: Patience, Grasshopper

Teacher’s note: This workbook lesson is intended to act as a pre test for the students to get them to think about what they already know. This will be the student’s first exposure to the concept as well as the context. It is important to spend time during this lesson to introduce the standard, walk the students through the format of the class, go over what they need to bring, how they should dress, any rules and expectations as well as the procedures around writing their reflections and workbook care. This lesson is short in the workbook because it is expected that the bulk of the lesson will be the teacher setting up their expectations and procedures for how the rest of the lessons will be undertaken as well as giving students an outline of the standard and the assessment. The pre test should be done at the end of the lesson for the last half hour. I encourage students to give every question a go and work on their own.
Lessons 1: Patience, Grasshopper

Before we delve into the exciting world of glitz and glamour that is karate for physicists, we need to see what we know, or what we don’t know. We are going to start with a written test. This is because we are taking the classroom theory to the practical. So let’s take our mechanics theories from last year and put them in a karate context. Then when we start the practical lessons, we have some theory to think about already.

Please answer the following questions in your book using blue or black pen only.

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In competitions, during the kumite rounds, competitors use gloves as well as shin and instep protectors. One reason for this is to protect their opponent. Explain why striking someone with an ungloved fist would be more damaging than a gloved fist even if the strike used the same amount of force.

One person runs towards and collides with a much smaller opponent who is standing still. Explain what you think would happen to the position and velocity of the two competitors after they collide.
Friction and other Forces
The following quote is from a website that manufactures mats for martial arts.

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Explain why, in terms of friction, a firmer mat is better for martial arts that involve fast foot movements.

Hooke’s Law and Springs
In hoju undo, students use a variety of different training aids to help them develop and strengthen their muscles. Two competitors are using the equipment shown below to work on their upper body strength.

One person is using the equipment as shown while the other has removed two of the springs from between the handles. Explain which person has the harder workout and how you decided.

Force components
Striking someone to the shoulder or head, more force is felt if the blow is struck vertically downwards rather than at an angle as shown. Why is this?

Vector addition of Forces
If you were trying to maximise the impact of your technique, why would it be better to pull your opponent towards you while punching them rather than just punching them?
Energy
Which opponent has more potential energy if they both fall on you with their full bodyweight from the same height, the one with more mass or the one with less mass? Why?

Acceleration and Velocity
If I run around the mat at a constant speed, I am accelerating but if I run across the mat at a constant speed I am not accelerating. Explain why.

Very good – you have finished the pre test!!
Lesson 2: A Journey of a Thousand Miles Begins with a Single Step

Teacher’s note: This lesson should take two class periods.

Lesson one practical activity:

10 minutes – warm up – introduce some basic punching and kicking techniques as part of the warm up.

10 minutes – have the students stand in a fighting stance with one student facing you. One student volunteer at the front facing the class. Go through with the students the concept of centre of mass. Where is their centre of mass? Is it different in male/female? Why is this? What is the base of support? What is the base of support when they are standing in a fighting stance?

10 minutes activity Stable Stances – have the students work with a partner and explore the following stances. One partner will stand in the stance and the other will try to (gently) push them over by pushing at the shoulder. Have the students discuss what happens with their partner.

<table>
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5 minutes – go over what the students found out and re-iterate base of support, centre of mass concepts

If the students are up to it – they can try basic punches and blocks in different stances and discuss which stances would be used for which types of motion and why (see table below for stances and kihon)

5 minutes – demonstration – trapped in the chair
Have a student sit in a chair. Ask them to get up. The person will be able to get out of the chair without much difficulty. Now, place your hand gently on the student’s forehead to prevent them from leaning forward and ask them to get out of the chair.

In order to leave the chair, your partner must shift their centre of mass from being over the chair to being over their feet. In order to do this, they will most likely lean forward to move the mass of their upper body over their feet and then stand up.

Remainder of class – students reflect/write notes on base of support and centre of mass

Lesson 2:

10 minutes warm up

Lesson two we take the centre of mass concepts from lesson one to allow us to have a stable base while performing a variety of kihon exercises.

For the practical component of the lesson, the students use pads and gloves vs ungloved hands and pads to practise punching. We discuss the construction of the safety equipment and how it works (impulse). The students practise punching and kicking kihon techniques ungloved on the bag and then gloved on the bag to feel the difference. As the glove crumples with impact the time of impact is extended and so while the momentum is the same, the force felt is smaller (change in momentum = impulse)

This lesson is very hands on and it is important to make sure that there are gloves and pads available for students but that even with safety equipment, students are not encouraged to full force punch or kick the bags. If this is the student’s first experience of Martial Arts, they should be encouraged to take it easy and slow so they do not hurt themselves. This is where I find demonstration is a good option.

Once again, students need time to reflect and write up what they have learned. Student notes are below.
Lesson 2: A Journey of a Thousand Miles Begins with a Single Step

Physics Focus: Forces, Centre of Mass and Momentum

The basics – These two lessons are an introduction to karate. Try hard to think of how Physics is integrated into the things that you are learning.

Class format

Every class will be composed of the same parts.

- Junbi undo – preparation exercises and warm up
- Kihon – basic movements and techniques
- Kata – prearranged forms – these are patterns that help you remember the kihon and show your understanding of techniques
- Kumite – sparring

There are other components, however, this is what we will be focussing on for this unit.

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Kihon (The Basics)
The following are some pictures to help you remember what you have learned in lessons 2 and 3.

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**Parts of the body:**
- **Gyaku:** upper area / head & neck
- **Chudan:** middle / shoulders & belt
- **Gedan:** lower / below belt
Lesson 3: Pop it, Lock it, Polka-Dot it

Teacher’s note: Again, this is a session that should run over 2 class periods. The teacher needs to be confident that the students are able to work with each other as there is a real potential to be hurt.

In the first lesson, start with the warm up, go over some kihon. The wrist lock is the easiest and most versatile and can be done in a variety of ways. Demonstrate first and have the students work in partners. The wrist lock can take a whole class period if it is explained thoroughly initially and the students are given the opportunity to practise on a variety of different partners. Once again, it is important to make time for the students to make notes.

In the second lesson, elbow and shoulder locks are introduced. Warm up and go over some kihon. A brief 5 minute run through of wrist locks with a partner accompanied by discussion can set the students up for the new locks. Demonstrate the new locks and have the students work in partners.

A fun exercise to do with students if they are working well is to have them face a partner in two lines. One line are the attackers and one line are the defenders. When the teacher calls go, the attackers attack with any attack they have learned and the defenders must choose and use an appropriate lock. Once this is done, the attackers move to the right, defenders to the left and they start again with a new partner.
Lesson 3: Pop it, Lock it, Polka-Dot it

Physics Focus: Forces and Torques

In this class we are looking at locking techniques or joint techniques. In the basics classes we focussed on techniques that relied on force, momentum, Impulse and linear kinematics principles. In the application of locks, we are looking at torques.

Locks are important tools for torque for two reasons. They allow you to more easily move someone about their centre of mass using their own arms or hands to create a distance from the pivot point of rotation. Also because we are dealing with bones and joints, the bones and joints of your body will respond when they are subjected to a torque in a way that will cause them to “Lock”

Locks that you should learn, know and love:

1. Wrist lock
2. Elbow lock
3. Shoulder lock

Theory:
Torque is the ability to start rotation around some pivot point. You can think of torque as rotational force. A rotational force will cause a rotational push and hence generate a rotational acceleration. If you think about something as simple as a drink can. The top operates on torque. Have you ever tried to open a drink and had the tab pop off? So annoying because it is hard to open the can without the tab, you can’t exert enough torque to open it. But put that same force to work at a distance from the pivot point by using the tab and it is easy to open a drink. Torque is a force with a distance from the pivot point.

\[ \text{Torque} = \text{Force} \times \text{distance} \]

This concept is applied against an opponent. If you wanted to rotate your opponent, you would not push on the centre of his chest because there is no distance from your applied force to his rotational centre of mass. You would push against the edge of his shoulder to cause him to rotate around his centre of mass. For even greater leverage, you could apply your force at his arm, say at the elbow. This is where the locks come in. Besides being uncomfortable to the opponent, a lock provides a way for you to make sure you have a solid hold at a distance from the pivot point which will allow you to easily move the opponent.

Another application of torque to a lock is in the actual lock itself. Because our joints are made of bones, the application of a torque will cause the joint to lock. Further application of the torque past the locking phase will cause bones to break. In this way, the application of a torque force can be a very effective technique.
Lesson 4: The Throwdown Showdown

Teacher’s note: These lessons have the potential to be highly dangerous as they involve falling. It is important to go step by step.

Lesson One:

Warm up

Introduction to break falling – discuss the reasons for breakfalling with the class. You can also talk to them about transferring momentum from linear to rotational and this is a demonstration that the students enjoy if there are two of you who are experienced enough to perform it. One karate-ka is thrown and instead of falling flat, tucks into a somersault.

Breakfalling step by step

- Have the students sit in front of a mat. The students then fall back and let their upper bodies impact the mat while stretching out their arms and hands and tucking in their heads.
- Once the students are proficient, move on to having them crouch on the mat and fall backwards in the same way.
- At this point, you can go through having them fall to one side or the other with one arm outstretched.
- Once they are proficient and comfortable falling from a crouch, they can try falling from standing onto the mat in the same manner being sure to stretch out the arms, hands, legs and tuck the head. Ensure that none of the students are jumping, they should be simply falling backwards.

Getting the students to a point where they can effectively breakfall generally takes one class period.

In the second class, we warm up by quickly running through the steps above. I then demonstrate the takedowns that we are going to learn – a simple step behind and a stepping forward to block a punch. I get the students to line up and I demonstrate on each student so I can evaluate their competence with breakfalling while being able to keep them from hurting themselves in the fall.

Once you are happy with the students ability to fall, break them into partners and have them try taking each other down. I have found that having my karate students on hand for this lesson is very helpful as I can put one of them with each pair or two pairs and they can keep a close eye on the students.

The circular motion takedown is done as a demonstration with the students observing unless they have been excellent students and I am confident they can perform the movement safely.
Lesson 4: The Throwdown Showdown

Physics Focus: Circular Motion, Acceleration and Gravity

Theory: Gravity is our friend in Karate. Mostly because gravity helps us take people down. Gravity is always pulling down on our centre of mass and so, by shifting the centre of mass, we can make an opponent fall. Once on the ground, the opponent is weaker than when they are attacking you from a standing position.

Acceleration due to gravity is 9.81ms$^{-2}$. Even just falling your head is going to experience a significant force, and, if we can lesson the time of impact, we can make falling a fairly painful event. Applying enough force to encourage your opponent to free fall under gravity is the main aim of the takedown.

When we are undertaking the lessons in takedowns, we will be using the gym mats to ensure safety. This is because of our old friends momentum and Impulse. Hit the unyielding gym floor from standing and the time of impact is very fast so the force you feel is very hard. Because you have the same momentum falling on a soft mat, and $p = F\cdot t$, falling on a soft mat increases the time of impact and so you feel less force.

How else can you make it hurt less? Break fall. There are a few things with the breakfall technique that you will learn but essentially there are two goals – 1. Spread the force of the fall out as much area of your body as possible and 2. Take the force on the “nonessential” parts of your body (arms and legs rather than neck and head).

We will also look at some circular motion takedowns. These are physically interesting because they make use of the principles of circular motion. You will try to turn as small a circle as possible causing your opponent to trace a large circle. This will cause them to accelerate and so they will fall down.
Lesson 5: I Came, I Saw, I Got Punched in the Face

Teacher’s note: This lesson is done in the classroom and concludes the formal learning in the unit. At the end of this lesson, I outline to the students what they are expected to do for the formal assessment, give them an outline of how I will grade their assessments and give them a timeline of when they need to be in. I have tried this in two ways. One giving the students class time to work on the assessment and one giving them no class time but putting the due date after the two week term break. The latter was more successful in terms of work quality and percentage of assessments returned.
Lesson 5: I Came, I Saw, I Got Punched in the Face

*Physics Focus: Mechanics Principles that you have learned*

Over the last few lessons, you have become a lean, mean, physics fighting machine. This is your chance to show the world what you have learned.

First, you need to find a red or other coloured pen. Go back and re take your Lesson One test, correcting any mistakes in the new colour. DO NOT REMOVE ANY PREVIOUS ANSWERS. You can add, change or annotate but make sure you previous answer is still readable.

Second, you have learned much in a short time, grasshopper. Now you must show it off.

You will need to present at least 5 Physics ideas in the context of karate. Any techniques that you have learned can be used. For example, you may want to explain how torque is useful in the different types of kicking (short distance vs long distance). You need to make sure that you ideas incorporate mechanics principles at level 3 of the Physics curriculum. You can discuss concepts from level 2 but remember that at level 3 you will need to show an in depth understanding of those concepts in addition to the work that you have done this year.

Just in case you’ve forgotten, here are the concepts that are covered in level 3 mechanics:

**Translational Motion**
Centre of mass (1 and 2 dimensions); conservation of momentum and impulse (2 dimensions only).

**Circular Motion and Gravity**
Velocity and acceleration of, and resultant force on, objects moving in a circle under the influence of 2 or more forces, Newton’s Law of gravitation, satellite motion.

**Rotating Systems**
Rotational motion with constant angular acceleration; torque; rotational inertia; conservation of angular momentum; conservation of energy.

**Oscillating Systems**
The conditions for Simple Harmonic Motion, angular frequency, variation of displacement, velocity and acceleration with time, phasor diagrams, reference circles, damped and driven systems, resonance, conservation of energy.

You may present your information in any way that you feel gets your ideas across. For example, you may choose to create a poster, write a report, record video of yourself performing movements – the format is up to you, the content is the important thing!
Physics 3.2 – Fight like a physicist

Name:__________________
Introduction

This booklet covers what you will need to know to pass Physics 3.2 “Demonstrate an Understanding of the Application of Physics to a Selected Context”. For this assessment you will be demonstrating your understanding of Physics to the selected context of Karate and demonstrate how physics will make you a lean, mean, fighting machine.

You will have 8 class periods of instruction to complete this unit of work. At the end of the unit you will be assessed both practically and through the presentation medium of your choice. The practical component of your exam may be recorded in accordance with NCEA moderation requirements.

What do you need to do to Achieve (and beyond) in this unit?

- Attend classes with a smile
- Attend make up classes if necessary
- Attempt all that is asked of you to the best of your ability
- Use your amazing powers of physics only for good, never evil
Lessons 1: Patience, Grasshopper

Before we delve into the exciting world of glitz and glamour that is karate for physicists, we need to see what we know, or what we don’t know. We are going to start with a written test. This is because we are taking the classroom theory to the practical. So let’s take our mechanics theories from last year and put them in a karate context. Then when we start the practical lessons, we have some theory to think about already.

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**Vector addition of Forces**
If you were trying to maximise the impact of your technique, why would it be better to pull your opponent towards you while punching them rather than just punching them?

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Very good – you have finished the pre test!!
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<td>Kyu</td>
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<td>Ju</td>
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<th>Stances</th>
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<td>Kokutso Dachi</td>
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<td>Striking Techniques</td>
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<tr>
<td>Gyaku Zuki</td>
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<tr>
<td>Kizami Zuki</td>
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<tr>
<td>Oi Zuki</td>
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<tr>
<td>Nukite Zuki</td>
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<tr>
<td>Mae geri</td>
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<tr>
<td>Mawahi Geri</td>
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<tr>
<td>Age uke</td>
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<tr>
<td>Chudan uke</td>
</tr>
<tr>
<td>Gedan uke</td>
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</tbody>
</table>

**Kihon (The Basics)**

The following are some pictures to help you remember what you have learned in lessons 2 and 3.
<table>
<thead>
<tr>
<th>Stances</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heisoku Dachi</td>
<td>Toes and heels touching</td>
</tr>
<tr>
<td>Musubi Dachi</td>
<td>Heels touching</td>
</tr>
<tr>
<td>Heiko Dachi</td>
<td>Parallel Stance</td>
</tr>
<tr>
<td>Shiko Dachi</td>
<td>Table Stance</td>
</tr>
<tr>
<td>Zenkutsu Dachi</td>
<td>Forward Leaning stance</td>
</tr>
<tr>
<td>Neko Ashi Dachi</td>
<td>Cat Stance</td>
</tr>
<tr>
<td>Hachiji Dachi</td>
<td>Natural Stance</td>
</tr>
<tr>
<td>Sagiri Ashi Dachi</td>
<td>Crane Stance</td>
</tr>
<tr>
<td>Sanchin Dachi</td>
<td>Hourglass stance</td>
</tr>
<tr>
<td>Benzoku Dachi</td>
<td>Crossed stance</td>
</tr>
<tr>
<td>Kokutsu Dachi</td>
<td>Back leaning stance</td>
</tr>
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<td>Striking Techniques</td>
<td></td>
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</table>

Parts of the body:

- Jodan: upper area (head and neck)
- Chudan: middle (shoulders to belt)
- Gedan: lower (below belt)
**Lesson 3: Pop it, Lock it, Polka-Dot it**

*Physics Focus: Forces and Torques*

In this class we are looking at locking techniques or joint techniques. In the basics classes we focussed on techniques that relied on force, momentum, Impulse and linear kinematics principles. In the application of locks, we are looking at torques.

Locks are important tools for torque for two reasons. They allow you to more easily move someone about their centre of mass using their own arms or hands to create a distance from the pivot point of rotation. Also because we are dealing with bones and joints, the bones and joints of your body will respond when they are subjected to a torque in a way that will cause them to “Lock”

Locks that you should learn, know and love:

7. Wrist lock  
8. Elbow lock  
9. Shoulder lock

**Theory:**

Torque is the ability to start rotation around some pivot point. You can think of torque as rotational force. A rotational force will cause a rotational push and hence generate a rotational acceleration. If you think about something as simple as a drink can. The top operates on torque. Have you ever tried to open a drink and had the tab pop off? So annoying because it is hard to open the can without the tab, you can’t exert enough torque to open it. But put that same force to work at a distance from the pivot point by using the tab and it is easy to open a drink. torque is a force with a distance from the pivot point.

Torque = Force x distance

This concept is applied against an opponent. If you wanted to rotate your opponent, you would not push on the centre of his chest because there is no distance from your applied force to his rotational centre of mass. You would push against the edge of his shoulder to cause him to rotate around his centre of mass. For even greater leverage, you could apply your force at his arm, say at the elbow. This is where the locks come in. Besides being uncomfortable to the opponent, a lock provides a way for you to make sure you have a solid hold at a distance from the pivot point which will allow you to easily move the opponent.

Another application of torque to a lock is in the actual lock itself. Because our joints are made of bones, the application of a torque will cause the joint to lock. Further application of the torque past the locking phase will cause bones to break. In this way, the application of a torque force can be a very effective technique.

**Lesson 4: The Throwdown Showdown**

*Physics Focus: Circular Motion, Acceleration and Gravity*
Theory: Gravity is our friend in Karate. Mostly because gravity helps us take people down. Gravity is always pulling down on our centre of mass and so, by shifting the centre of mass, we can make an opponent fall. Once on the ground, the opponent is weaker than when they are attacking you from a standing position. Acceleration due to gravity is 9.81ms⁻². Even just falling your head is going to experience a significant force, and, if we can lesson the time of impact, we can make falling a fairly painful event. Applying enough force to encourage your opponent to free fall under gravity is the main aim of the takedown.

When we are undertaking the lessons in takedowns, we will be using the gym mats to ensure safety. This is because of our old friends momentum and Impulse. Hit the unyielding gym floor from standing and the time of impact is very fast so the force you feel is very hard. Because you have the same momentum falling on a soft mat, and p = F·t, falling on a soft mat increases the time of impact and so you feel less force.

How else can you make it hurt less? Break fall. There are a few things with the breakfall technique that you will learn but essentially there are two goals – 1. Spread the force of the fall out as much area of your body as possible and 2. Take the force on the “nonessential” parts of your body (arms and legs rather than neck and head).

We will also look at some circular motion takedowns. These are physically interesting because they make use of the principles of circular motion. You will try to turn as small a circle as possible causing your opponent to trace a large circle. This will cause them to accelerate and so they will fall down.
**Lesson 5: I Came, I Saw, I Got Punched in the Face**

*Physics Focus: Mechanics Principles that you have learned*

Over the last few lessons, you have become a lean, mean, physics fighting machine. This is your chance to show the world what you have learned.

First, you need to find a red or other coloured pen. Go back and re take your Lesson One test, correcting any mistakes in the new colour. **DO NOT REMOVE ANY PREVIOUS ANSWERS.** You can add, change or annotate but make sure you previous answer is still readable.

Second, you have learned much in a short time, grasshopper. Now you must show it off.

You will need to present at least 5 Physics ideas in the context of karate. Any techniques that you have learned can be used. For example, you may want to explain how torque is useful in the different types of kicking (short distance vs long distance). You need to make sure that you ideas incorporate mechanics principles at level 3 of the Physics curriculum. You can discuss concepts from level 2 but remember that at level 3 you will need to show an in depth understanding of those concepts in addition to the work that you have done this year.

Just in case you've forgotten, here are the concepts that are covered in level 3 mechanics:

**Translational Motion**
Centre of mass (1 and 2 dimensions); conservation of momentum and impulse (2 dimensions only).

**Circular Motion and Gravity**
Velocity and acceleration of, and resultant force on, objects moving in a circle under the influence of 2 or more forces, Newton’s Law of gravitation, satellite motion.

**Rotating Systems**
Rotational motion with constant angular acceleration; torque; rotational inertia; conservation of angular momentum; conservation of energy.

**Oscillating Systems**
The conditions for Simple Harmonic Motion, angular frequency, variation of displacement, velocity and acceleration with time, phasor diagrams, reference circles, damped and driven systems, resonance, conservation of energy.

You may present your information in any way that you feel gets your ideas across. For example, you may choose to create a poster, write a report, record video of yourself performing movements – the format is up to you, the content is the important thing!
Appendix 4 – Workbooks created in Support of a Series of Workshops run for the General Public at the New Zealand International Science Festival

Students were issued with a metal ring clip with the first booklet. They could then clip the additional booklets in to have all three together if they attended all three workshops.
Fight like a Physicist

Workshop 1: Crouching Tiger, Standing Crane
Introduction

This booklet covers what you will need to know for Workshop 1 in the Fight Like a Physicist series.

3 Rules:

- Attend workshop with a smile
- Attempt all that is asked of you to the best of your ability
- Use your amazing powers of physics only for good, never evil

Karate Class format

Every class will be composed of the same parts.

- Junbi undo – preparation exercises and warm up
- Kihon – basic movements and techniques
- Kata – prearranged forms – these are patterns that help you remember the kihon and show your understanding of techniques
- Kumite – sparring

There are other components, however, this will get you started

Language

Usually, Japanese is used for counting, technique names, and instructions. Here is a guide to help you with some of the Japanese you might hear in workshop 1.

Japanese vowel sounds are pronounced the same way as they are in Māori.

<table>
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<tr>
<th>General Commands</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>Onegai shimasu</td>
<td>Please teach me</td>
</tr>
<tr>
<td>Shugo</td>
<td>Line up</td>
</tr>
<tr>
<td>Kiyotsuke</td>
<td>Stand (At attention)</td>
</tr>
<tr>
<td>Rei</td>
<td>Bow</td>
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<tr>
<td>Hajime</td>
<td>Start</td>
</tr>
<tr>
<td>Yame</td>
<td>Stop</td>
</tr>
<tr>
<td>Arigato gozaimashita</td>
<td>Thank you</td>
</tr>
<tr>
<td>Hai</td>
<td>Yes</td>
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<td>Ju</td>
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<td>Stances</td>
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<td>Heisoku Dachi</td>
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<td>Musubi Dachi</td>
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<tr>
<td>Kokutso Dachi</td>
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</table>

What do you and an orbiting satellite have in common?

Ok let’s be honest not too much. One is out in space, you are here on Earth, one is in orbit, one is reading this sentence...

But what is keeping the satellite in orbit?

That’s right, the same force that is keeping you on the planet, is keeping a satellite from spinning off into the dark void of space. And another thing, the Force of gravity by the Earth on the satellite, is acting through the centre of mass of the satellite. Just like the Force of gravity by the Earth on you, also keeping you from spinning off into the dark void of space, is acting through your centre of mass.

Your centre of mass is about three fingers below your belly button.

You can confirm to yourself that your centre of mass is about 44% of your height (or about 3 fingers below your belly button) but how?

You need:
- 2 bathroom scales
- A piece of wood you can lay down on
- A tape measure or metre ruler

Method:
1. Measure your mass on one scale
2. Set up the piece of wood on the two scales
3. Lie down on the wood and record the mass on each scale
4. Your total mass should be the same as adding the two scale readings together (plus the wood)
5. The distance from the top of your head to your centre of mass is
   
   \[
   \text{distance} = \frac{(\text{foot scale reading} \times \text{height})}{(\text{foot scale} + \text{head scale})}
   \]

NOTE: this is using balanced torques so you can derive this formula yourself if you are super keen 😊
It is very important in karate to know about your centre of mass because:

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Other things I learned today:
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Circle the face that shows how you feel about the statement.

1. I enjoyed the workshop:

|NO!!!| not really| Don’t know| it was ok| YES!!!|
|😊😊😊|😊😊😊|😊😊😊|😊😊😊|😊😊😊|

2. I would come to another workshop:

|NO!!!| probably not| Don’t know| probably would| YES!!!|
|😊😊😊|😊😊😊|😊😊😊|😊😊😊|😊😊😊|

3. I would tell my friends to come to a workshop like this:

|NO!!!| probably not| Don’t know| probably would| YES!!!|
|😊😊😊|😊😊😊|😊😊😊|😊😊😊|😊😊😊|

What I liked the best about the workshop:

What I think could be improved:
Fight like a Physicist

Workshop 2: Angry Bull, Crazy Monkey

Page 118
Introduction

This booklet covers what you will need to know for Workshop 2 in the Fight Like a Physicist series.

3 Rules:

- Attend workshop with a smile
- Attempt all that is asked of you to the best of your ability
- Use your amazing powers of physics only for good, never evil

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Every class will be composed of the same parts.

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- Kata – prearranged forms – these are patterns that help you remember the kihon and show your understanding of techniques
- Kumite – sparring

There are other components, however, this will get you started

Language

Usually, Japanese is used for counting, technique names, and instructions. Here is a guide to help you with some of the Japanese you might hear in workshop 2.

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<td>Bow</td>
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<td>Start</td>
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<td>San</td>
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<td>Shi</td>
<td>4</td>
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<td>Go</td>
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<td>Hachi</td>
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<td>Kyu</td>
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<td>Ju</td>
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</table>
### Striking Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Gyaku Zuki</td>
<td>Reverse punch</td>
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<td>Gedan uke</td>
<td>Lower block</td>
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</table>

**Spoiler alert! The little guy wins:**

Momentum is the “stoppability” of an object. It is critical to karate because it is made up of two components, mass and velocity. This dual nature of momentum is critical to a small person’s ability to overcome a larger. If the small person is fast, they can make up for their lack of mass.

Utilising the mass aspect of the relationship means that even if we have small, low massed arms, we can increase the effective mass by putting our entire body behind the technique and using as much of our mass as possible. A punch where you stand still and just throw your arm out will have less momentum than a punch where you are moving forward with your entire mass as your arm moves out.

Momentum is also related to Impulse. That means that the more momentum you have, the more Impulse you have. Because Impulse is Force $\times$ time of impact, that means that by increasing the velocity of your technique, you can increase the force your opponent feels, even if you have less mass.

Torque is the ability to start rotation around some pivot point. You can think of torque as rotational force. A rotational force will cause a rotational push and hence generate a rotational acceleration. If you think about something as simple as a drink can. The top operates on torque. Have you ever tried to open a drink and had the tab pop off? So annoying because it is hard to open the can without the tab, you can’t exert enough torque to open it. But put that same force to work at a distance from the pivot point by using the tab and it is easy to open a drink.

This concept is applied against an opponent. If you wanted to rotate your opponent, you would not push on the centre of his chest because there is no distance from your applied force to his rotational centre of mass. You would push against the edge of his shoulder to cause him to rotate around his centre of mass.

Torque can also be used at specific parts of the body – the joints. Our joints are made of bones and the application of a torque can cause the bones to reach their maximum range of motion and “lock”. This is useful for two reasons – the first is that the lock allows you to have a solid hold at a distance from the person’s pivot point. The second reason is in the actual lock itself. If the torque is applied past the locking phase of the joint, the joint can suffer serious tendon and/or ligament damage as well as potentially broken bones.
How can someone with less mass in their arm muscle generate a punch with as much force as a larger massed person?

______________________________________________________________________________
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What is one situation you can think of not mentioned in the workbook that illustrated the principle of torque?

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Other things I learned today:
______________________________________________________________________________
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Circle the face that shows how you feel about the statement.

1. I enjoyed the workshop:

   NO!!!  not really  Don’t know  it was ok  YES!!!

2. I would come to another workshop:

   NO!!!  probably not  Don’t know  probably would  YES!!!

3. I would tell my friends to come to a workshop like this:

   NO!!!  probably not  Don’t know  probably would  YES!!!

What I liked the best about the workshop:

What I think could be improved:
Fight like a Physicist

Workshop 3: Throwdown Hoedown
**Introduction**

This booklet covers what you will need to know for Workshop 3 in the Fight Like a Physicist series.

3 Rules:

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<td>Kyu</td>
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<td>Ju</td>
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</table>
That's not flying, it's falling, with style...

Gravity is our friend in Karate. Mostly because gravity helps us take people down. Gravity is always pulling down on our centre of mass and so, by shifting the centre of mass, we can make an opponent fall. Once on the ground, the opponent is weaker than when they are attacking you from a standing position.

Acceleration due to gravity is $9.81\text{ms}^{-2}$. Even just falling your head is going to experience a significant force due to this acceleration. If we can lessen the time of impact, we can make falling a fairly painful event. Applying enough force to encourage your opponent to free fall under gravity is the main aim of the takedown.

When we are undertaking the lessons in takedowns, we will be using the gym mats to ensure safety. This is because of our old friends momentum and Impulse. Hit the unyielding gym floor from standing and the time of impact is very small, so the force you feel is very big. Because you have the same momentum falling on a soft mat, and momentum is $\text{Force} \times \text{change in time}$, falling on a soft mat increases the time of impact and so you feel less force.

How else can you make it hurt less? Break fall. There are a few things with the breakfall technique that you will learn but essentially there are two goals – 1. Spread the force of the fall out over as much area of your body as possible and 2. Take the force on the “nonessential” parts of your body (arms and legs rather than neck and head).

What is going to happen to this balloon when the hand applies a force and pushes it towards the nails??
Spreading the force of the fall out over as much area of your body as possible is important because:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Taking the force on the “nonessential” parts of your body (arms and legs rather than neck and head) is important because:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Other things I learned today:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Circle the face that shows how you feel about the statement.

1. I enjoyed the workshop:

   NO!!!  not really  Don’t know  it was ok  YES!!!

2. I would come to another workshop:

   NO!!!  probably not  Don’t know  probably would  YES!!!

3. I would tell my friends to come to a workshop like this:

   NO!!!  probably not  Don’t know  probably would  YES!!!

What I liked the best about the workshop:

What I think could be improved: