PICTURES AND CASES: DEVELOPMENT OF CASE-BASED TEACHING COURSEWARE TO IMPROVE STUDENT UNDERSTANDING OF STATISTICS

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ABSTRACT

Cohorts of students in economics and business classes often find the theory and fundamentals of statistics difficult to grasp. This paper outlines how a student-centred case-based teaching approach for inferential statistics, combined with educational technology, can make a significant contribution to teaching statistics in a traditional University undergraduate lecture-oriented statistics course. The author explores the advantages of using pictorial icons within a problem learning environment. Also provided is empirical evidence supporting some success using this approach. Findings suggest that students' fundamental understanding of concepts improve, the overall course failure rate reduces, and student engagement with the teaching material increases.

INTRODUCTION

It is widely accepted that statistics students have negative perceptions of statistics as well as difficulties in mastering fundamental concepts (Cochran 2005, Kotz 2010, Prabhakar 2008). Garfield and Ben-Zvi (2007) argue that statistics education is emerging as a discipline in its own right, with a proliferation of research studies appearing into the teaching and learning of statistics and probability. Today's introductory statistics course is actually a family of courses taught across many disciplines and departments; with students having different backgrounds and goals (Aliaga, et al. 2012:10).

Literature related to teaching and learning statistic pedagogical methods, instructional formats, and technological tools, finds that students are often faced with general mathematical problem solving issues. Further, they have problems understanding concepts specific to statistics such as an incomplete understanding of control variables inferring causality from correlation, or confusing probability with typicality (Murtonen and Lehtinen 2003).

Technology is also increasingly playing a larger role in the education of students of statistics (Ben-Zvi 2000, Chance et al. 2007); however, the authors stress the importance of choosing an appropriate technology tool that enhances student collaboration and student-instructor interactions instead of a poor technology that causes students to spend more time learning to use the software than applying it. A further constraint to successfully learning statistics arises from a failure to provide learning experiences in problem solving (Norman, Henk, and Schmidt 2000). These issues may be compounded as some commentators suggest that many teachers may have limited statistical content knowledge as well as little, if no, exposure to any specific pedagogy related to the teaching of statistics (Froelich, Leinmann and Thompson 2011, Sorto 2011). This further reduces students' statistical literacy development with many quickly falling behind resulting in a disliking for statistics.

To counter this with an aim to have students gain a more meaningful and valuable experience in their learning, the author developed a case-based teaching method that includes a set of illustrations as visual cues, called Pictorial Icons (PI), that assist in the delivery of abstract mathematical concepts to students in an engaging, easily understood manner. Cases are an active learning paradigm of guided inquiry embedded in problem-based instruction (Problem Based Learning) where learners are presented with a problem scenario (or case) from which to imagine and research potential outcomes and conclusions (Andrews, Hull & Donahue 2009). The case-based method was chosen as research studies have indicated that case studies facilitate and promote Active Learning, help problem solving, and encourage the development of higher order critical thinking skills through the interpretation of information and the creation of ideas (Boston University, undated; Kaddoura, 2011; Nair, et al. 2013; Popil, 2011). The benefits of the case experience are derived from the interaction between the problem, task and setting (Bruner, 2004). Similar applications are found with Marriott, Davies and Gibson (2009) who review how teachers of statistics have gradually proposed changing the way statistics is taught to make it more relevant by drawing on real problems in real contexts. The chosen approach is also in line with the call for using authentic, real world problem contexts for the teaching of statistics, as recommended in the Guidelines for Assessment and Instruction in Statistics Education (GAISE, 2005), which state that statistics educators, specifically, should foster active learning in the classroom through techniques such as group problem solving, hands-on activities and discussion.

After experimenting and trialling this teaching method for three years with positive verbal and written student feedback, as well as improved learning outcomes, the author wanted to test the pedagogical effectiveness of this case-based approach for teaching statistics. It was hoped that integrating the approach with a multimedia web-based software package that delivers statistics materials as problem-based learning scenarios would increase students' engagement, develop effective problem solving skills as well as accelerate the practical transfer of relevant course-specific knowledge involving the normal distribution, sampling distributions, confidence intervals and hypothesis testing.

This paper presents empirical findings from research into integrating technology into a statistics course. It also investigates the impact and effectives of the techniques used in the authors' student-centred case-based teaching methods in an undergraduate statistics course. In addition, this paper explores the benefits available to educators and students of incorporating this teaching technique with online interactive eLearning software. The results suggest that a combination of Pictorial Icons, embedded within eLearning scenarios, can enhance both student motivation and student problem solving abilities. Some reflections are offered on the implications of adopting case-based learning as a method of teaching inferential statistics.

CAN CASES AND PICTURES HELP STUDENTS TO UNDERSTAND STATISTICS FUNDAMENTALS?

In 2005 the GAISE College Report asserted that introductory statistics has been taught almost the same way for 30 years, and that most students don't learn what they need to know in modern society (Aliaga, et al. 2012). As early as 1990 Dallal argued that statistics students are frustrated by their courses, finish with no useful skills, and are turned off the subject for life. In our own experiences at teaching university level introductory statistics we often encounter students who experience preconceived ideas that statistics is something to be feared as they struggle to understand key concepts. A challenge of large university courses is the diversity that comes with heterogeneous student populations possessing different cultural backgrounds, mathematical literacy, styles, expectations and background knowledge or skills required to fully understand the material. The result is that students find statistics concepts hard to grasp and hard to work out how to apply them to the real world.

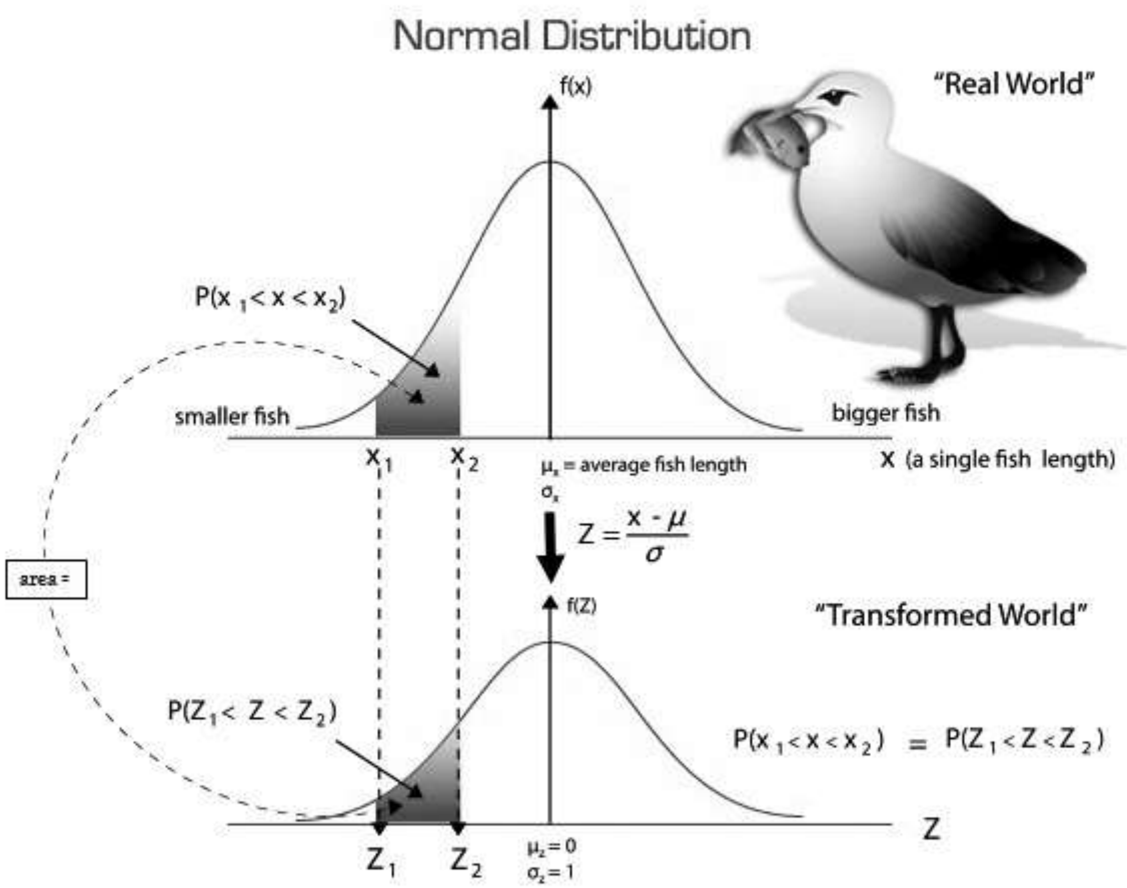
The research reported in this paper aims to partly address how to help students grasp difficult statistical concepts and apply them to real world problems. There is a plethora of empirical evidence that Active Learning 'learning by doing' is vital for understanding. For example, Rodenbaugh, Lujan and DiCarlo (2012) argue that active learning enhances student performance on examinations and improves student retention of course content. Similarly, Lee (2007) reported success when using chocolate chip cookies in class for demonstrating many statistical concepts. After many years lecturing and tutoring large, first year undergraduate statistics courses, typically with 750 enrolments, the author developed a teaching method that uses a series of linked real-world based cases to illustrate statistical concepts. In doing so, a set of illustrations, Pictorial Icons, evolved to accompany the cases used to help students clarify abstract mathematical concepts. This helped to engage students, as the case and illustrations could be easily understood and related to real-life experiences. By using linked scenarios and simple cases, key concepts such as the normal distribution and the sampling distribution of the mean are able to be explained in an engaging manner. This approach enables students to compile a cognitive image and make mental linkages to enable difficult concepts to be understood and readily recalled, as described by Trafimow (2011) who demonstrates a technique proving statistical theorems that can be explained quickly with pictures where students grasp the concepts and better understanding of the theorem with pictorial presentations.

COURSEWARE CREATING NON-TRADITIONAL CASE-BASED TEACHING METHODS

Four case studies of a mock fish farm called 'Silver Lining Fish Farm' have been developed introducing inferential statistics topics; the normal distribution, sampling distributions, confidence intervals, and hypothesis testing. The case studies are developed as courseware, or 'scenarios' in the Scenario Based Learning Interactive (SBLi) eLearning software. Simply put, a scenario is a learning environment focused on a specific problem or realm of enquiry. The software was chosen, as it is an easy-to-use multidisciplinary eLearning tool with its pedagogical origins in problem-based learning (PBL) and situational learning theory (University of Queensland 2011). Each subsequent scenario builds on the theoretical concepts and learning from the previous scenario. This approach enables students to practice relevant concepts on a particular topic before confidently proceeding to the next scenario that builds upon the knowledge from the previous scenario. Theoretical concepts are represented using pictures, which are the key to the scenarios. The aim is to help alleviate the discouraging cumulative effects students can experience if they fall behind. Multiple choice quizzes and short answer questions are applied during the scenarios to evaluate and review student performance, and to provide instant feedback thus reinforcing learning outcomes. In solving the various fish farm problems presented in all four scenarios, students are ultimately required to reach a final conclusion based on work covered. Whilst progressing through the scenarios, there are items students should collect such as data sets and tables. Ultimately, as students work through all four scenarios, they need to continually reflect on the question, 'Would I buy the Silver Lining Fish Farm?' using data collected and analysed for such things as fish sales, farm expenses, profitability etc. Through the gathering of information and using statistical analysis techniques in a real-world context, students are ultimately required to advise their client whether or not to purchase this fish farm as a viable business proposition.

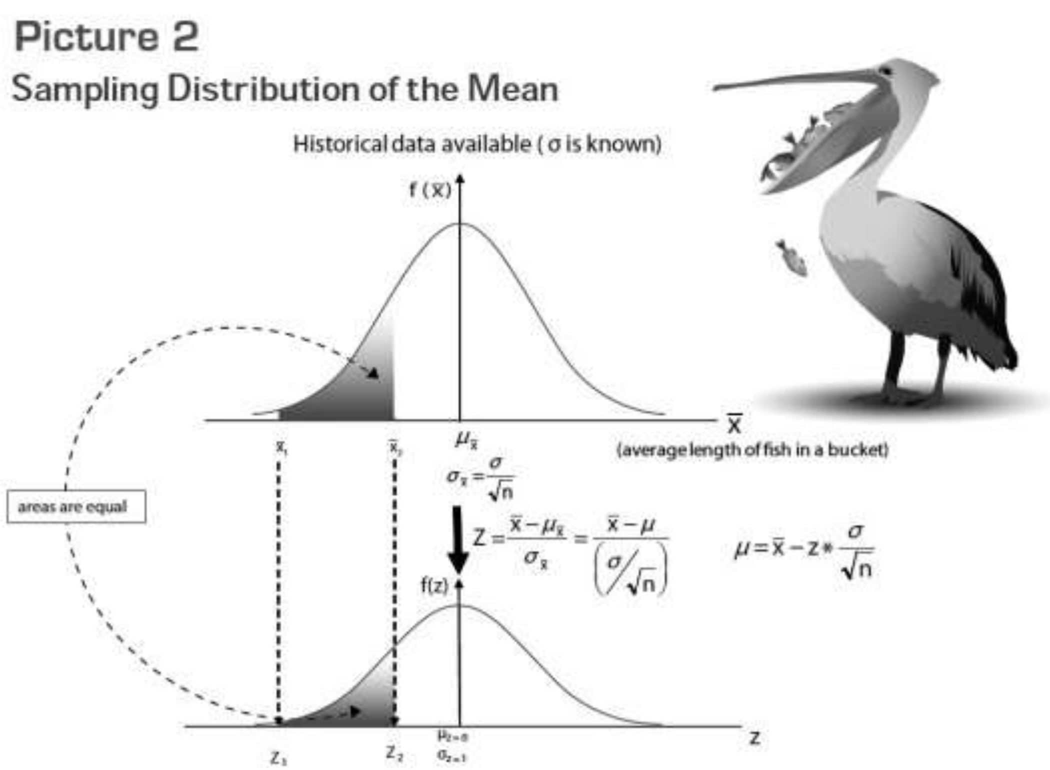
Concepts such as the normal distribution and the sampling distribution of the mean have been explained using simple characters such as a seagull and pelican catching fish from a large pond. These characters and cases capture the essence of the mathematical relationships in the bird-fish domain, and this helps invoke their analogous meanings in the statistical domain. For example, the length of a single fish (the variable), that could be caught by a seagull diving into the fish farm pond, is explained as being normally distributed within the population of all fish in the pond. Fish in the pond form the population of interest. It can be easily understood by students that some individual fish lengths are smaller than the mean length fish at the centre of the distribution, many fish lengths will be located near the mean, and some fish lengths will be larger than the mean. A seagull is used to represent the act of catching a single fish and, as such, becomes the Pictorial Icon that is associated with the normal distribution where the variable refers to a single item (a fish length). Equations relating to the transformation of the 'real world' variable of fish lengths to a 'transformed' Z variable can then be captured diagrammatically. This helps consolidate a fundamental concept needed to build up an understanding of inferential statistics. Thus the concepts involved with the normal distribution is captured in the seagull analogy i.e. a picture of a seagull with a single fish in its beak, see Figure 1.

Figure 1
THE SEAGULL PICTORIAL ICON LINKED TO THE NORMAL DISTRIBUTION



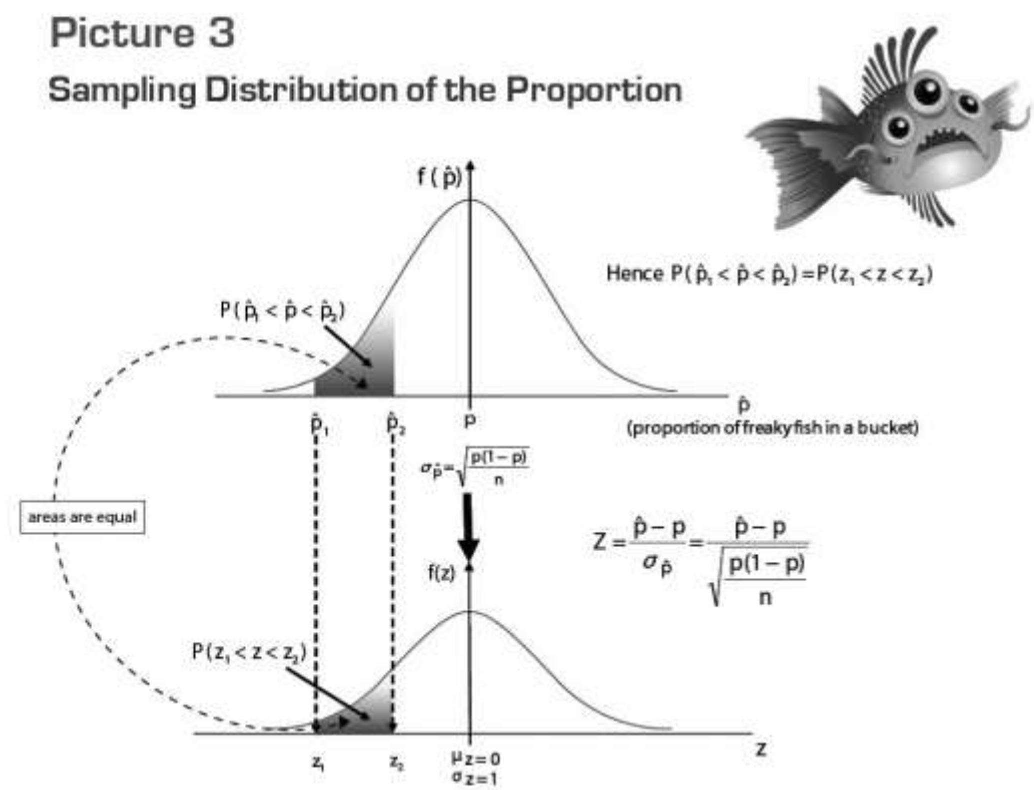
Having understood the normal distribution, the sampling distribution of the sample mean is then introduced. This is a very conceptual topic that students struggle to understand. Developing a conceptual understanding of statistics has been widely discussed in the literature (Trafimow 2011, Vargas-Vargas et al. 2010). In an attempt to create an analogy to explain the sampling distribution of the sample mean, a pelican catching several fish in its bill at a time is introduced. It is then possible to explain that when the pelican catches a bill full of fish, this can represent a sample. This sample average length of fish that the pelican has caught could be calculated. If the pelican catches the same number of fish each time (same sample size), many times over, the theoretical sampling distribution of the sample mean can then be built up and explained to students in simple terms. Once again a visual analogy is created and the pelican image is used to relate to sample means where the population standard deviation is known. The sampling distribution of the sample mean concept and pelican are shown in Figure 2.

Figure 2
THE PELICAN PICTORIAL ICON, RELATED TO THE SAMPLING DISTRIBUTION OF THE MEAN.



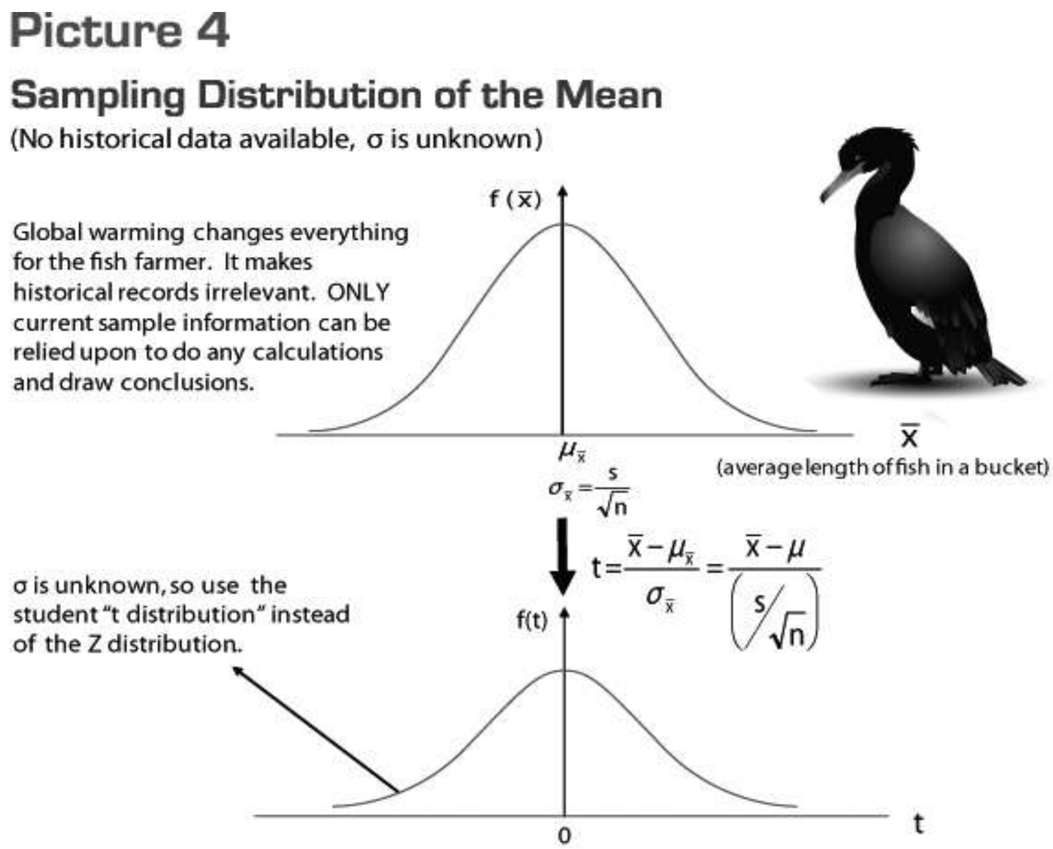
Another fish farming analogy is used to convey the concept of the theoretical sampling distribution of the sample proportion. Here, it is assumed the fish on the farm are contaminated with a pesticide from an industry nearby. As a consequence, some of the fish become deformed and have three eyes (or some other related strange characteristic). This then enables a description of gathering random samples (in buckets) so as to work out the sample proportion of freaky fish (in the bucket). In a similar way to the sampling distribution of the mean, it can then be explained how the theoretical sampling distribution of the sample proportion can be found. In doing so, students can see the similarities between the two theoretical sampling distributions and begin to appreciate the linkages to particular problem types. The visual analogy with the freaky fish and sampling distribution of the sample proportion is seen in Figure 3.

Figure 3
THE FREAKY FISH PICTORIAL ICON, RELATED TO THE SAMPLING DISTRIBUTION OF THE SAMPLE PROPORTION.



To distinguish between the sampling distribution of the sample mean when the population standard deviation is known (σ) and when it is unknown, a new Pictorial Icon is introduced. The image of a 'shag' or cormorant is used to create a link as to when to use the t-distribution (as opposed to the Z-distribution and the Pelican when σ is known). In inferential statistics, it is highlighted how characteristics of the population, such as σ, are usually not known. In the fish farming analogies, it is possible to illustrate that new conditions can occur on the farm. For example, an increase in water temperature can change the growing characteristics of fish resulting in differences to previously collected historical data. This would mean that using such things as σ from previous observation is likely to result in incorrect inferences being made under the new conditions. Hence it is explained how the t-distribution becomes important. The Pictorial Icon of the shag and use of the t-distribution transformation is shown in Figure 4.

Figure 4
THE HERON PICTORIAL ICON, RELATED TO THE SAMPLING DISTRIBUTION OF THE MEAN.



Therefore, environmental impacts on farming activities and using Pictorial Icons to make connections with theoretical concepts and real problems to solve, linkages involving statistical concepts are able to be explained in a meaningful way to students. The Pictorial Icons and the cases have been designed to improve students' understanding and application of inferential statistics techniques, increasing student awareness in applying statistical concepts in real-world situations (i.e. not just text book learning), and an improved student ability to observe, analyse and interpret quantitative information. The method of linking the Pictorial Icons to theoretical concepts enables students to build effective mental models, the theory is easier to understand because it is being taught in terms of useful everyday events that students already understand.

APPLICATION IN UNIVERSITY COURSES

The four scenarios are taught each semester to law, engineering, arts, economics, social science, tourism and hospitality, and business students who have enrolled in a University introductory undergraduate statistics course ECON1310 (Quantitative Economic and Business Analysis A); which is an introductory course that covers basic statistical concepts and techniques such as descriptive statistics, probability concepts, theoretical distributions, inferential statistics (confidence intervals & hypothesis testing) as applied in business and economics.The course helps students develop an ability to apply inferential statistics techniques to independently solve practical problems and to then explain the solutions using everyday language. This course is widely regarded as challenging by many students partly because the work is totally cumulative meaning that it is exceptionally difficult to catch up if a student gets behind. Success in the subject depends on students keeping up-to-date with the subject matter. Student assessment consists of a one-hour mid-semester exam with multiple-choice, short answer, and a problem solving format (25%); five quizzes each worth 4 percent covering topics from lectures and tutorials (20%), and a two-hour final examination which examines work from the start of lecture five (i.e. normal distribution) onwards through to the last lecture, again consisting of multiple-choice, short answer, and a problem solving format (55%).

Enrolled students have a wide range of mathematical abilities that need to be catered for in order for them to grasp key statistics concepts. Access to the scenarios is provided via the University's Blackboard website. The scenarios are designed to support and enhance the lectures and clarify concepts with a focus on using real-world situations. It is intended, at a later date and upon further refinement, to incorporate the scenarios into the course as an assessable item. The scenarios were introduced to undergraduate students in semester one, 2010. Initial feedback from both students and staff members exposed to the scenarios has been positive with many students having accessed the scenarios during their course.

METHODOLOGY

Research Design

A study was designed to test how much conceptual understanding could be gained from working through online scenarios with the theory available when needed. Students from all thirty-six tutorial groups (those with and without the Pictorial Icon (PI) teaching) were asked to volunteer to work through the eLearning scenarios in semester 1, 2010. At the beginning of the semester students are required to select a tutorial slot from the options provided on the University's Blackboard system. Students self-assigned themselves to a tutorial group based on their timetable availability and what time/day was most suited to them. Students are, however, required to remain in their tutorial slot for the duration of the semester once making their selection. Tutorial procedures are strict. Students are not allowed to change groups without a request in writing and receiving approval from the Course Administrator. Thus, tutorial groups maintained some stability and students were classified into one of four groups, shown in Table 1 below, which indicates the expected outcome for each group in the design.

Tutorials gave practical experience in data analysis and allowed students to further synthesise and revise the challenging concepts faced in this course. A mixture of teaching approaches was applied to the tutorial groups, as indicated in table 1. The selection of what approach to apply per group was made by the Course Administrator. Some tutorials followed the same case-based technique used in lectures and implemented in the eLearning software. The cases were further illustrated by the pictorial icons used to help students develop mental concept maps in recalling the details of different topics and establish mental connections between the picture and the theory.

Additionally, two focus groups were run at the end of the course, using a set of topics that enabled students to discuss their impressions regarding both the Pictorial Icon (PI) analogies and the eLearning scenarios. The author led the focus groups; during the final tutorials students were informed of the study intention and asked to volunteer. Those that volunteered to participate joined the focus group at an agreed time, were given instructions and asked to sign a statement of voluntary participation (refer to appendix).

Objectives

Our research objective was to assess the learning impact of the constructivist case-based teaching approach that uses pictures to form linkages to appropriate theory and how this practice, embedded in technology, can improve statistical literacy. We expected that students participating in tutorials using the bird-fish analogies only (PI instruction; No SBLi) would do better at understanding theoretical concepts than a control group. We then expected that students using the SBLi software (SBLi only; No PI instruction) would do better on application questions than the control group and the PI only group. Finally, we expected that students who participated in tutorials using the bird-fish PI's as well as using the SBLi scenarios (the full treatment group) should do better on both theoretical and application questions.

Any learning advantage of the PI groups over the control group would indicate the importance of effective guided instruction for successful problem solving. Furthermore, if the SBLi groups showed further advantage over the PI instruction alone, this would suggest that some amount of additional understanding is created by applying learned concepts to real world scenarios. It would also give some empirical support for constructivist approaches to teaching statistical theory. If no extra advantage is found, it could be concluded that effective instruction alone is sufficient for learning complex statistical theory.

Research Question

The following research question developing from the above stated objectives has guided the study:

Can case based teaching exemplifying real-world situations embedded in educational technology help students' theoretical understanding and improve their problem solving and statistical literacy?

Pre/Post Test Instrument

To answer the research question each group in the design was given a pre-test and a post-test list of statements relating to a real world problem regarding the purchase of a small take-away suburban fish and chip shop business. A series of business orientated questions requiring an understanding of statistical concepts were presented to the students in the form of a questionnaire. Students were required to select from a set six statements only three they believed to be most correct. The choices presented were all applied type statements relating to a fish and chip shop business. The students then needed to select from a second set six statements only three statements that they believed to be most correct. The choices presented in this second set of statements were all applied type statements relating to the fish and chip shop business, designed to stress conceptual understanding, rather than mere knowledge of procedures. Students were scored on the number of correct options that they chose. With each set of statements a total of three correct responses could be made by the student. This same survey set of questions was given to the students to do once again near the end of the course after attending the lectures and tutorials. This allowed a theoretical and an application score out of three to be obtained both before and after students had taken the course (please refer to the appendix for a copy of the pre-post-test and instructions to students).

RESULTS

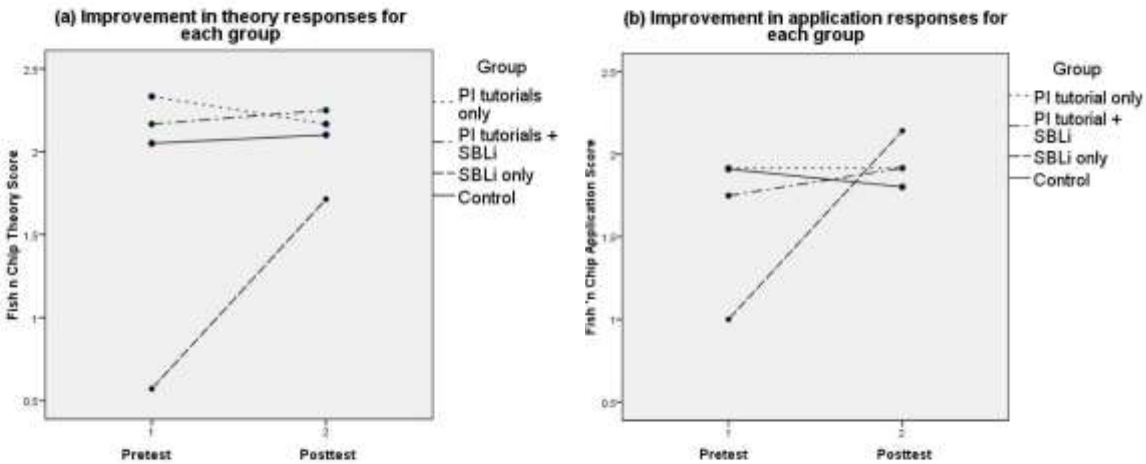
Table 2 shows the average exam marks for each group in the study at the end of semester 1, 2010. Since students were self-allocated to tutorials and to eLearning scenarios, the numbers in each cell of the design are not evenly distributed. Participation in the survey was optional; the difficulty was getting students to participate due to their busy study schedule. However, since the numbers were enough for a preliminary investigation, we proceeded with the analysis.

Table 2 reveals that there were some surprising results. As expected, the control group had the lowest mean (53) for exam marks. Furthermore, the students who were taught using the PIs had a mean (57) that was four points higher than the control group, and students who used the SBLi software as well as being taught using the PI's had a mean (59) that was six points higher than the control. However, students who used the SBLi software only and did not attend any of the PI classes had a mean (70) that was 17 points higher than the control, and higher than every other group in the study.

Possible effects of the experimental groups were analysed using ANOVA's. The results revealed that there was a significant difference somewhere amongst the four groups (F3= 2.28; p = .04). However, post-hoc tests showed that these effects were only due to the significant differences between the SBLi and the control groups. That is, the students who used the SBLi performed significantly better in the exams than any other groups. While the students in the PI groups (i.e. that took the author`s tutorials) had higher means than the control group, the sample sizes are too small to allow any differences between this group and any others to be significant.

Given that the SBLi only group was very small, it could just be that the significant result for the exam was a random anomaly. Or, it could be that these were just the brightest or most motivated students, who used all materials available (i.e. the SBLi scenarios) to study for the exam. In order to investigate this result more closely, we then inspected the pre-test versus post-test patterns for each of these groups on both the theoretical and applied concepts.

Figure 5
PRE-TEST VERSUS POST-TEST SCORES FOR EACH EXPERIMENTAL GROUP (A) FOR THE THEORETICAL QUESTIONS AND (B) FOR THE APPLIED QUESTIONS.



The number of correct statements that students gave on the pre-test versus post-test fish farm problems were compared using two-way ANOVAs, for both the theoretical questions and the applied questions. While there was only a small variance from which to detect any differences, the results, graphed in Figure 5, showed that there were improvements from the pre-test to the post-test for some of the groups. For the theoretical questions, there was a significant interaction between test occasion and experimental group ($F3= 2.88$; $p=.04$). Post-hoc tests showed that the significant effects were due to the SBLi group producing a large pre-test to post-test improvement while neither the PI tutorials alone nor the PI tutorials plus SBLi showed any significant improvements across the test occasions. This may have been because these groups already had high scores so that there was little room for improvement from the pre-test. Furthermore, the SBLi only group, while starting much lower than the other groups, still ended up with a post-test mean lower than all other groups for the theoretical statements. All other groups showed no significant changes from the pre-test to the post-test for these statements.

The results showed that for the applied questions, the interaction between test occasion and experimental group was also significant ($F3= 4.35$; $p=.005$). Furthermore, while starting out at a much lower score, the SBLi only group greatly improved on the applied questions, to the extent that this group ended up with a post-test mean comparable to the other three groups when comparing the scores on the applied statements. All other groups showed no significant changes from the pre-test to the post-test for these statements.

The significant improvements for the SBLi group could have been because the SBLi group started with very low scores on the pre-tests for both theory and application questions. If so, that result is interesting, because the analysis of the exam marks in Table 2 showed that these same students obtained the best exam marks by far. We originally interpreted this exam result by suggesting, previously, that the SBLi only students could have just been the brighter students. However, the fish and chip shop pre-test survey data in Figure 5 shows that initially, these students had the least knowledge! By combining the results of the fish farm tests with the exam results, we are lead to conclude that the higher exam marks of the SBLi group was not a result of these students having a higher-level of intellect. Rather, the SBLi experience gave these students an advantage in the exam. It also gave these same students a significant improvement in their applications aspects, as well as an improvement (but not an advantage) on the theoretical aspects, of a real world problem. Together these results suggest that the SBLi experience probably helped with the applied aspects of the exam (i.e., problem solving).

An analysis of examination results over recent years provides some evidence to support the positive outcomes attributed to this teaching approach. The results for the introductory statistics course from 2005 to 2011 are summarised in Table 3.

In semester 1, 2010, all students were asked to complete a survey in the first week of the course with only 410 completing a follow up second survey in the last week of the course. There were 832 students enrolled in the course at the time (since semester 1, 2010, SBLi and the Pictorial Icon teaching approach was not used in semester 2, 2010, but was used again in semester 1, 2011).

STUDENT REACTION AND PRELIMINARY RESULTS

"*A great course. I found it interesting but I understand why some students might find stats very dull. Regardless, it [the course] teaches you a lot about how businesses gather information and make decisions in the real world*" Jessica, ECON1310 student semester 1 2014.

As this comment above demonstrates, student reaction to the eLearning activities and the course has been typically positive. On the day of demonstrating the use of the software scenarios in lectures, there is typically a noticeable increase in the level of attentiveness, enthusiasm and participation. On official University student evaluations for the course completed by students, there are now regular written comments indicating how the SBLi scenarios and case-based teaching approach are highlights of this undergraduate statistics course. On exam questions that relate to the normal distribution, sampling distributions, confidence intervals, and hypothesis testing, student understanding has been seen to clearly improve through both verbal communications with them as well as observing improved exam outcomes.

Overall user feedback from the eLearning scenarios has been positive; with many students indicating they believed using the software had helped greatly in their understanding of concepts. Student comments regarding the course can generally be summarised as: eLearning provides opportunities to revise course materials, pictures provide clarity of core concepts, and interactivity provides stimulation and interest in materials. Student comments suggested that the eLearning scenarios also helped with understanding the concepts. The students said that they liked the scenario problems with the screen-casts included, because it helped them to revise e.g. "You can use the scenario lesson to go over it again after the tutorial, when you need it and Tutorials go a million miles an hour. The scenario doesn't have the same questions as the tutorials, but it has the same theory that you need for the tutorials (which gets skipped over in the tutorials)." It also helped them to focus on the elements of the theory that were the most important; e.g. "it focuses on what's important…lectures and the textbook give too much detail." Students liked that the materials were presented visually and verbally; e.g., "Visual or verbal learner, it's all there and I like that it is in text as well. I am not a visual person, I need words." The class also had a large percentage of students with English as a second language, who made comments like "the screen-casts help me to understand because I can hear Carl as well as see what he is talking about."

From the author led focus group discussions involving eight students some light was shed on what advantages for student learning may have been provided by the eLearning tool. Students found the interactive experience motivating; e.g. "*You don't have to come to uni. I hate* *reading a book, I don't mind sitting on the net, it's [the SBLi scenario] not monotonous. It's interesting. It relieves the study condition of sitting there," and "I only did stats because I have to; however, this way, you learn it."*

The focus group participants gave very specific comments regarding the effectiveness of the visual analogies; e.g. "*The pictures linking up with the theory gives me more clarity… I picture what he [the lecturer] is saying; e.g. when he says 'sampling distribution' I think of a bird with a bucket in its mouth, which makes me think further of the Z-formulae, and further still, that it needs a sample size, a mean, X-bar and a standard deviation and everyone has experienced fish in a pond and in a bucket, so everyone can relate to those and I don't even say proportion any more, I say freaky fish."* These types of comments suggest that the bird-fish analogies were effective teaching tools that aided understanding, and that the Pictorial Icons were being used to remind students of the entire analogy. Even though the data did not show the advantage of these analogies for the PI groups over the control group, these comments suggested that the bird-fish analogies were well understood and appreciated by some of the students.

This is also reflected in the much improved passing rates in the final exam in semester 1, 2010 (86 percent) and semester 1, 2011 (89 percent) compared to previous years where no changes to the course material delivery or exam style format occurred. The examination procedure and questions in both semesters 1, 2010 and 2011, were very similar to the previous ten years of the course. This involved a 90-minute mid semester exam and two-hour final exam. Both exams consisted of multiple choice questions and short answer calculation style questions. Indeed, previous lecturers in the course wrote the majority of the exam questions for semester 1, 2010. This was to help eliminate any bias in comparing exam result outcomes with previous years by ensuring the author did not set an "easy exam."

Students' historical pass rates increased from approximately the mid 70 percent area in 2005, to 86 percent pass rate in semester 1, 2010 when SBLi was first introduced (refer table 3). Feedback provided by students in the semester1, 2010 course was generally very positive after exposure to both the case-based method of teaching and the SBLi scenarios. Student feedback indicates a general increase in interest for the subject. Below is some of the received written feedback provided from students who trialled the resources:

"SBLi had helped me to gain insight and the steps required to solve real-world problems."

"When I did use it (SBLi), it was just as easy to work through tutorial questions and realise where I went wrong, rather than just seeing the wrong answer."

"It's more interactive, I think. It's easy to tune out during Lectopia."

"Even though I didn't get far into it, it is definitely interesting to learn the practical applications of what we are studying not just the theory."

When asked what was the most useful thing learned from the course, one student made the following insightful, if not humorous, response concerning the practical application of what she learned;

"SBLi helped me to acquire vocational skills and understand the approach to solving real-world problems. Like the standard normal curve, and how many human measurements conform to the probabilities it contains. As a girl who likes tall men, I would use it to judge whether a current boyfriend is worth sticking with, based on the probability of finding a taller one."

DISCUSSION

This paper has described an approach that teaches undergraduate statistics through presenting material using simple cases and examples illustrated with pictures to put difficult concepts into context. In addition, it has outlined the benefits of presenting the material using scenarios and eLearning software. This was the first time the eLearning software (SBLi) had been used in this way in order to teach inferential statistics concepts.

The findings from this preliminary investigation into the benefits this teaching approach brings are positive. This has been assessed primarily from focus group discussions, written evaluations from users, as well as verbal feedback from many students. An initial focus group in 2009 found that from a limited amount of responses from users that there was a significant improvement in students understanding of important inferential statistical concepts. However, while this was only a pilot study it did provide a sense that further investigation into the effectiveness of the teaching approach warranted further investigation.

Stewart, Brown, and Weatherstone (2009) observe that an illustrated narrative, or story, is often the manifestation of the problem-based scenario paradigm in an eLearning context. They argue that the use of interactive problem-based scenarios in educational contexts has been founded on the premise that students learn better by active engagement (i.e. doing things). Michael and Modell (2003) observe that learning is an active process, while Martí et al. (2006) state that Problem-Based Learning (PBL) is an educational strategy to improve student's learning capability that, in recent years, has had a progressive acceptance in undergraduate studies.

The active learning paradigm of PBL seemed applicable for application in a statistics educational context, as it is aimed at evoking student motivated, improving student ability to observe, analyse and interpret quantitative information, and developed a sound understanding of the underlying concepts. In addition, scenario-based learning is also recognised as active learning with the efficacy of scenario-based learning in health science education being especially well documented for example (Hoffman et al. 2006, McLoughlin, Burns, and Darvill 2015, Poulton et al. 2014). What is not so well documented is the efficacy of scenario-based learning in statistics education.

Considering that PBL activities make problems relevant and have been shown to increase student engagement, the question arose as to whether a case-based approach combining PBL would help student cognitive engagement and subsequent understanding of statistical concepts. It has been demonstrated across various disciplines that the efficacy of the PBL format over more traditional methods is thought to offer significant advantages in the acquisition of knowledge and underlying educational theory, motivation enhancement, as well as promoting self-directed learning (Kiernan et al. 2008, Gallagher and Gallagher 2013

Klegeris and Hurren 2011). Evidence from other disciplines suggests there are indeed likely benefits for students from implementing a PBL approach to teaching inferential statistics.

The author wished to address the pedagogical effectiveness of combining web-delivered problem-based learning scenarios with the picture illustrated case-based teaching method developed. The software was chosen in part because Scenario Based eLearning places an emphasis on internalised learning where learners are able to assess situations and react appropriately; creating more realistic and fluid dynamic learning experiences (Kindley 2002), because the authoring tool does not require any programming knowledge and is adaptable to specific contexts, plus students' involvement with materials is active and goal based. In addition, building an electronic student tool appeared to be the next logical step in augmenting this novel teaching approach in a flexible, cost effective, interactive manner. The software has also been previously demonstrated as highly motivational for students and enables independent problem solving abilities to be developed using real-world simulations (Blackburn 2011, Gossman et al. 2007, Stewart 2007).

Combining eLearning software with a non-traditional case-based teaching method is an original approach to using technology in order for statistics students to recognise problem types and learn how to solve them. A series of fully interactive eLearning scenarios were developed to enable students to make choices and interact with an environment where they are presented with real-world technical issues. The fish farm analogies previously used by the author in teaching inferential statistics theory where incorporated into the eLearning scenarios. The scenarios apply multimedia materials to capture student interest and engage students in the learning process by building linkages between mathematical formulae and real-world applications.

The software has been developed as a cognitive tool for the design of problem based simulations in an eLearning environment that will facilitate problem solving, critical thinking and higher-order learning. It takes advantage of the educational benefits of problem based learning and combines it with the flexibility and engagement of interactive multimedia providing students with a more realistic and fluid educational experience. Students become engaged in the process of critical thinking and problem diagnosis, involving iterative cycles of enquiry, reflection, and hypothesis generation.

RESEARCH CONCLUSIONS

The research presented in this paper shows that eLearning scenarios designed to emphasise conceptual understanding rather than mere knowledge of procedures may significantly benefit students who struggle to develop problem solving skills. Specifically, eLearning software allows guided instruction to be incorporated with just-in-time learning principles.

Given the small sample sizes in some of the cells in this study, it is unwise to draw any hard and fast conclusions from the data. The study presented here is currently being repeated with more students in each cell of the design. In addition, the repeated study also provides more statement options for students to select from in the fish farm pre-test and post-test problems. Students are now required to select the best five options from a list of ten specific questions. This is an improvement over the first survey study as it allows for more variance in the data. Furthermore, a full test of the relative importance of effective instruction and of experience alone could be performed. This would involve comparing the eLearning scenarios described in this paper (that use embedded screen-casts and analogy based teaching), with a new series of eLearning scenarios relying on students experiencing spread sheets and graphical tools only (without any embedded explanations).

The use of effective visual analogies embedded in technology is a cognitive teaching tool that appears to promote positive benefits when teaching difficult concepts in introductory statistics. Although a full and independent evaluation of PBL for education in large undergraduate statistics classes is yet to be undertaken, this paper argues that PBL, combined with a case-based teaching approach and Pictorial Icons embedded in educational technology can make a significant contribution to professional training in inferential statistics on the basis that it stimulates student motivation and promotes deep learning on a number of levels. Further rigorous experimental design and research is needed to investigate whether PBL intervention in a traditional curriculum is more effective than an exclusively didactic statistics programme.

However, it is important to recognise the potential benefits student-centred PBL has in relation to the life-long learning of future statisticians.

Table 1
EXPECTED OUTCOMES FOR THE FOUR GROUPS.

1.	Pictorial Icon (PI) instruction	No Pictorial Icon (PI) instruction
SBLi	Full treatment (Better on both)	SBLI only (Better on Applications)
No SBLi	Pictorial Icon only (Better on Concepts)	Control

Table 2
VALUES SHOWN ARE: AVERAGE EXAM MARK; STANDARD DEVIATION; AND SAMPLE SIZE RESPECTIVELY.

	Pictorial Icon (PI) instruction (the author's tutorials)	No Pictorial Icon (PI) instruction (other tutors)
SBLi	59; 17; 14	70; 12; 8
No SBLi	57; 17; 38	53; 18; 350

Table 3
PASS RATES FOR UNIVERSITY COURSE ECON1310 QUANTITATIVE ECONOMIC AND BUSINESS ANALYSIS (TOTAL NUMBER OF ENROLLED STUDENTS INDICATED IN BRACKETS)

Year	Semester 1	Semester 2
2005	70% (745)	60% (365)
2006	77% (761)	62% (396)
2007	76% (766)	67% (456)
2008	79% (880)	77% (481)
2009	79% (697)	78% (421)
2010	86% (832)	76% (400)
2011	89% (762)	-

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APPENDIX

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

School of Economics
ECON1310
Semester 2, 2009

Dear Student, **1ST ROUND**

The following exercise is part of a research project. In this exercise, specific teaching techniques are being examined to measure their effectiveness in helping students learn statistical concepts. In particular, our aim is to assess the impact of scenario based learning. To evaluate this teaching method, we need to look at your current understanding of statistics and your ability to apply statistical knowledge. Later in the semester, we will redo this same exercise after your participation in ECON1310.

To enable proper analysis of the data, we are asking you to supply your **8-digit student number** with your answers in this exercise. UQ ethical standards specify that the lecturer will not see any of the information or answers you supply. Infact, an outside researcher will be collecting the data and analysing it. This will be strictly followed. Thus, your answers in this exercise will be c**onfidential** at all times and are not part of the assessment for this course. Please be assured once the information is analysed, the master file will have your student identification totally removed. At no time will any individual student be able to be distinguished. Furthermore, your participation in this exercise is completely voluntary and you are free to withdraw at any time. If you consent to participating, and for the researcher to use your information as outlined, please sign below.

I have read the explanation above. I understand my participation in this exercise is voluntary and that my privacy will be protected. I agree to provide my student number to assist with data collection and analysis.

Signed ____ date: ______________

Thank you for your participation.

8 digit Student Number: _ _ _ _ _ _ _ _
ECON1310: Fish 'n Chip Shop Scenario Purchase Decision Survey

The scenario you are presented with below involves collecting data for the purchase of a local Fish 'n Chip shop. If you answer the scenario questions to the best of your ability, it will be used as benchmark for your current grasp of statistical concepts.

Scenario

A friend of yours has asked for help in deciding if they should purchase a Fish 'n Chip shop that is for sale. The current owner has told your friend that, on average, the shop serves 500 customers each week, and makes a monthly pre-tax profit of $10 000. Your friend needs your knowledge of statistics to help decide if the shop has the characteristics the owner claims.

Some features of a fish 'n chip shop business can be assessed using statistics. The variable your friend has asked you to focus on is the shop's **average daily sales** (as you need to make a purchase decision after one month). You have no access to official records of all daily sales for this particular shop, so the owner's claims cannot be directly verified.

By collecting data on daily sales for this shop over a one-month period, you could (**tick** all those you believe are **true**):

☐ 1. Calculate the average sales for all fish 'n chip shops in the local area.
☐ 2. Create a sample of daily sales.
☐ 3. Calculate the population mean of daily sales.
☐ 4. Estimate the population proportion spending more than $20 on each visit.
☐ 5. Calculate average monthly sales for one year.
☐ 6. Calculate the sample mean and standard deviation of daily sales.

Now you need to go out and collect data for the fish 'n chip shop purchase decision. **Tick** the **three (3) most important** tasks below that you would perform so as to **collect data** and then be able use so as to make an informed purchase decision.

☐ 1. Visit the shop, on random nights during the month, and count the customers.
☐ 2. Visit the shop, observe and record what customers buy.
☐ 3. Visit other local fish 'n chip shops in the area recording what is bought.
☐ 4. Visit the shop on random nights, then buy and taste the food.
☐ 5. Collect sales data from another fish 'n chip shop to compare with your sample.
☐ 6. Ask customers how much they spent.