Effects of ICT Simulation and Traditional Experiments on Preservice Students' Experiences in the Concept of Photo Electric Effects

Govender Nadaraj
University of KwaZulu-Natal, Faculty of Education, South Africa
Email: Govendern37@ukzn.ac.za

Abstract

This qualitative study explored preservice physics students' experiences when engaging in PhET simulations and traditional hands-on practical experiments on the Photoelectric Effect. A control and experimental groups were set up with different sequences of traditional and simulation experiments. Students were interviewed on these experiences. Audio-interviews were recorded with the students expressing their interactions and conceptual understandings with practical equipment using the Photoelectric Effect and with corresponding ICT simulations. Students' classroom interactions were viewed from a constructivist perspective. Results suggest that students find the simulations on the Photoelectric Effect stimulating and traditional practical work essential for developing certain skills. While the simulations helped them to comprehend the theory, observations and graphical aspects are better and present a holistic experience of the topic; it did not assist them in the procedure, technical aspects and social interaction of experiments. In developing a thorough understanding of the overall experiment many students could not account for the inferences of the experiment and also poorly interpreted the graphs. Given that students had poor school practical experiences, they valued guided traditional experiments with timely pedagogical interventions from the instructor rather than open-inquiry. The simulations allowed them greater visual perception of the micro-aspects of the phenomena. The study recommends that students should be exposed both experimental and simulations set-up of the Photoelectric Effect as each promotes different skills in physics.

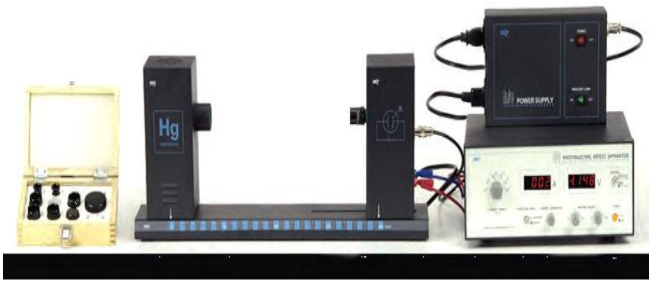
Key words: Photoelectric Effect, simulations, nature of Light, experimental work

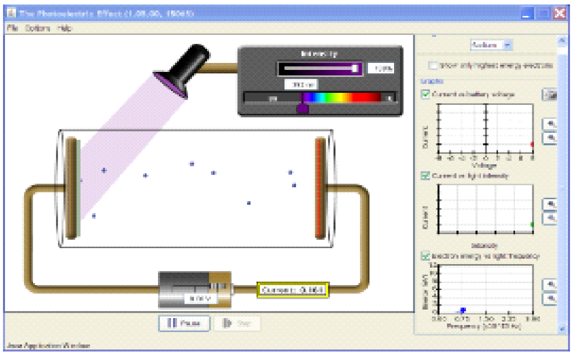
11. INTRODUCTION

Deep conceptual understandings of physics and the use of technology and related skills have become a common part of essential modern techno-society. The development of technological ICT resources such as simulations, computer programmes for storing and analysing data etc. contribute to important skills that can support both content learning and save valuable time and effort and promote autonomous learning. Science performances, both at tertiary and schooling are reportedly poor in SA and in other countries (Bernstein, 2005). While several problems of learners' poor results point to historical inequities, reports also indicate that teachers' poor subject content knowledge and lack of pedagogic knowledge in using ICT resources and the lack of school policy implementation are major obstacles to the learners' efficient performances (Mumtaz, 2000). In education, while great strides have been made in other countries such as the UK, US, Japan, India, Singapore, Turkey, etc., in using and researching the effectiveness of computers and ICT in teaching and learning of physics and other disciplines, there is still a wide gap between ICT policies and school implementation in SA (Howie & Blignaut, 2009). The White paper on e-Education in South Africa advocates all educators to be ICT literate by 2013. Given that preservice teacher education has good potential to influence students' future use of ICT, it is imperative that teacher educators have to constantly design, evaluate and reflect on preservice education for effective integration of ICT into discipline areas to improve performance in learning. Innovative and updated preservice education on the use of ICT is also important because it can help to counter the possibilities of transmission-oriented school practices when novice physical science teachers begin their careers. Significant amounts of research have been done in both design features and school-classroom use of ICT worldwide but little in teacher education in the area of simulations in learning and teaching physics in Africa, hence our niche contribution.

Computer interactive science simulations software such as PhET (Physics Education Technology Project developed by the University of Colorado, Boulder) can provide scaffolding in the form of access to domain knowledge especially in physics (Wieman, Perkins, & Adams, 2008) and serve as a focal point for discussion between educators and students, and provide a space in which to coordinate concrete representations of abstract ideas together with physical phenomena (Adams, 2010). This study extends this perspective and explores preservice physics students' experiences when engaging in traditional experiments in Physics (Figure 1) and PhET simulations (Figure 2) on the Photoelectric Effect (P.E). The topic reflects an important development on the nature of light in physics and shows how physics theory and experimentation are mutually interactive. This challenging experiment which provided support for the photon theory of light was developed by Philip Lenard in 1902 (and extended by Millikan in 1914) and eventually explained by Planck and Einstein in 1905. The topic is also covered in the Further Education and training (FET) school Physical Science curriculum, hence preservice teachers' understanding of the concepts and development of practical skills are crucial to improving learner performance at school. Also given that the P.E. experimental equipment (Figure 1) is expensive to purchase by schools, other innovative strategies of teaching this topic need to be exercised; for example, free ICT PhET software simulations are easily downloadable (Figure 2) and used in this study.

Figure 1: Photoelectric Effect laboratory Figure 2: PhET Photoelectric Effect simulation PASCO equipment





12. LITERATURE

Pedagogy can be crucial in any type of learning activity and as such is always at the heart of any application of educational innovation. Students may attend ICT training courses and learn such as how to “surf the net” or develop web pages, but these skills must be placed in a pedagogic context. Students must be shown how to re-focus their work and lessons to take account of maximising ICT learning (Kalogiannakis, 2010). The lack of ICT for science laboratory work was the most commonly reported obstacle by technical coordinators. Hence, simulations such as PhET provide a valuable substitute or additional resource.

South Africa has made some progress in terms of the implementation of ICT in education. The majority of schools are still in their development stages regarding the acquisition of ICT and most of those who have access are still in the process of trying to integrate ICT into their teaching and learning (Howie & Blignaut, 2009). It is pedagogically important that we ensure that our prospective teachers are comfortable and capable to integrate ICT into the classroom teaching environment (Birch & Irvine, 2009). There is some evidence that as teachers become aware of the ICT resources that are easily available such as PhET simulations etc., they will to exploit their use in classrooms. Currently, tertiary physics students and post-graduate science education students are exposed to ICT software either through their use in classrooms or in researching in their post-graduate degrees. Thus a more refined and deeper exploration of the use of ICT simulation in particular difficult topic areas becomes necessary to advance learning and pedagogy. Computer simulations are widely used in physics instruction because they can aid student’s visualization of abstract concepts; they can provide multiple representations of concepts in visual forms such as graphical, trajectories, charts, etc. They can approximate real-world examples, and they can engage students interactively in problem solving (Cox, Junkin III, Christian, Belloni, & Esquembre, 2011).

Concepts in Light are abstract and light as a wave-particle duality can be confusing. While experiments in elucidating the wave nature of light can be done fairly easily and grasped, the particle nature and Einstein’s explanation of P.E. is not easily assimilated and understood, even after tutorials and practicals. Simulations allow concepts such as electric current in the P.E. which cannot be directly observed in experimental set-up can be represented on a computer screen paired with a representation of the physical phenomenon under study (see Figure 2).

13. THEORETICAL FRAMEWORK

The study examines how students interact via the *constructivism framework* in using PhET interactive simulations in ICT learning. Constructivist theory acknowledges that learners are not absorbers of knowledge but active participants in constructing their own meaning based on strongly held preconceptions (Glasersfeld, 1989; Tobin, 2008). For learning theorist Piaget (1985), human inquiry is rooted within the individual, who constructs knowledge through his or her actions on the environment. Piaget views the direction of the development of thinking from the individual to the social. Teaching strategies that embodies the aspects of content most relevant to its teachability such as analogies, illustrations, examples, explanations, demonstrations improve students’ ability to scaffold knowledge and thus forming multiple links of concrete and abstract concepts. Both practical work and simulations can strengthen associations and links that scaffold knowledge. Simulations and laboratory practical work build knowledge in ways of representing and formulating the subject that make it comprehensible to students and to others whom they have later to teach. Hence, preservice students’ pedagogy must include an experience of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions (alternative conceptions) that students of different ages and backgrounds bring with them to the learning and an awareness of sequencing of activities (curriculum development) in scaffolding knowledge and skills. In this study, the main focus was on the cognitive process of learning physics and to uncover difficult concepts and essential skills that students experience in understanding the P.E. and how their interaction with laboratory equipment and ICT simulations unfold.

14. KEY QUESTIONS

iii) What are Physical Science preservice students' cognitive experiences in using the simulations in understanding the nature of Light via the Photoelectric Effect?

iv) What are Physical Science preservice students' perceptions of sequencing of theory, laboratory practicals and simulations in understanding the nature of Light via the Photoelectric Effect?

15. METHODOLOGY

5.1 Simulations and Laboratory Equipment

PhET simulations developed by the University of Colorado team (Adams, 2010) provide fun, interactive, research-based simulations of physical phenomena in science. PhET research-based approach incorporated findings from prior research and their own tests, enabling students to make connections between real-life phenomena and the underlying science, deepening their understanding and appreciation of the physical world. PhET simulations also help students to visually comprehend concepts by animating what is invisible to the eye through the use of graphics and intuitive controls such as click-and-drag manipulation, sliders and radio buttons. In order to further encourage quantitative exploration, the simulations also offer measurement instruments including rulers, stop-watches, voltmeters and thermometers etc. Students also used the traditional, hands-on but latest PASCO laboratory equipment of the P.E. The detailed manual supplied by PASCO offered students with procedural and safety measures to take when obtaining results.

5.2 Method

Seventeen (18) physics preservice students were exposed to engaging in PhET simulations from a learning perspective in a physics laboratory with internet access, using LAN in tutorial time and the internet after hours at home. Two weeks consisting of three double lecture periods (1 lecture= 40 min) for each week were used: 2 periods to cover the content theory and tutorials of Light-Wave and Particle nature, 8 periods for practical work including engaging in PhET simulations in Light and P.E. and 2 periods for assessment, discussion and reviews. Students were familiar with PhET simulation packages from exposure to earlier modules taught. The online PhET site was used directly in class and some students had their own computers and software downloaded as well. The different packages on Light were examined and the P.E. simulation was focused for this study. Tutorial problems (Figure 2) were given to students to solve after using the simulations and completing practical work in P.E. While each student worked in pairs during the simulations, students were encouraged to collaborate and dialogue with others in larger groups. For the traditional experiment, two large groups were formed due to limited equipment and time. Initially all students were exposed to a brief review of the classical nature and wave nature of Light and an overview of how to proceed with the P.E. practical. One group was exposed to practical work first and then the simulation and vice versa for the other group. Students were interviewed singly and the interviews were audio-recorded with their permission. Students were given conceptual questions on the P.E. and assessed in tests and examinations. The qualitative data from these interviews formed part of the analysis and answers the first research question. Individual and whole classroom reflective discussions were held towards the end of the 2 week session. The data from these interviews answers the second research question. The audio-recordings were reviewed several times and transcripts were made of relevant clips. Some of the interview transcripts are used in the qualitative data analysis of this study.

16. RESULTS AND ANALYSIS

16.1 Feedback on the design features of P.E. simulations vs laboratory equipment

PhET simulations provide attractive graphics, animation and bright colours. In the case of 'electric current' and colour of light in the P.E., the visual presentation of the set-up and graphs made an impact on students' understanding but the traditional experiment used a closed ammeter and only readings were obtained, leaving students to draw the graphs later. Thus real-time data and visualization not normally experienced as visuals in the laboratory environment enhanced memory and associations of current with intensity of light and frequency with the colour of light used (see interviews).

Interviewer: What features you find interesting in the PhET simulations for P.E.?

Sipho: We can also change the color of light with the same frequency. When you change it from blue to red we know that blue light have higher frequency than red light.

Bhengu: It's attractive, easy to use and colourful… and interactive.

Interviewer: Is it better than laboratory work?

Justice: It is the same but this saves time and safer. You can also see the direction of electrons and graphs are drawn at the same time.

Peter: Simulations are fun, so it is enjoyable, it doesn't require much, everybody likes to work with ICT so to focus and get immediate attention. I find it easy but to get where the attention is directed is more difficult because you working with a computer and enjoying the features of the simulations. Unless you are asked questions, conceptual questions then you get to think about what is happening- here the educator can help.

Haby: Simulations helped me to visualize the microscopic view of the electrons, more electrons and more energetic and other concepts that are hard to understand. It was nice to see the microscopic parts like the electrons because it helps us understand the abstract ideas.

Aneel: I found the simulation easier than the actual practical, because in the P.E. simulation, I have a visual understanding of what does an ejected electron looks like, this was difficult in the practical.

Haby: But you cannot change anything in the simulation, you cannot get the graph with exact input readings as in the laboratory work. In the simulation you cannot stop and start, but I still think in the practical even if you do not get it now you can come back to it later and get data. Most of my work has been practical work so I am familiar with the

> taking of results and doing the practical, so I have more technical skills because I am familiar with the apparatus, but the concept of calibration I only got when I went through the theory to understand why did we did it.
>
> *Aneel*: I understand that we have to calibrate the apparatus but I do not know why I am doing the calibration of the apparatus.

16.2 Focusing on scaffolding information by forming links and associations

In making sense between intensity and frequency, the simulations helped to develop basic conceptual relations clearly first, namely the relationship between frequency of light, its colour and the energy of the electrons. Then second relationship was developed, namely, intensity of light and the number of photoelectrons. These are not easy associations to be made quickly from the P.E. traditional experiment. The P.E. simulations provided a holistic understanding of the P.E. and then students could easily follow and understand the laboratory practical.

> *Sipho:* The simulation shows the electrons emitted, and it is easy to understand the relationship between the intensity and the number of electrons emitted. We can also change the color of light with the same frequency. When you change it from blue to red we know that blue have high frequency than red light, so the energy of the emitted electrons will be less than those in red light because energy is related to wavelength and frequency. It also helped to understand that because some of the light does not emit any electrons in certain metals, no matter how hard you shine the light it still does not eject any electrons. This means that for different metals we have different work functions.

Comment: We see that the simulation experiment was useful in helping Sipho to come to associating the nature of work function of metals to different frequencies of light.

> Interviewer: How do simulations compare with the laboratory practical work?
>
> Sipho: I think the simulations can help you understand generally. It cannot develop the technical skills. It can only develop your understanding of the theory. It can help you to come to a theory even if you didn't know anything and then confirm with the theory that is already developed. The thing with the actual apparatus is that you have to use figures, draw graphs in order to come to a conclusion in attempt to understand the deeper theory and it takes a long time.
>
> *Rueben:* A bit of theory is required then you can see it from the simulations but then in the actual simulations you can visualize it through the graphs. You think more in order to understand the concepts. A disadvantage with the simulation is that it is limited, it does not give you all the current values, voltage values, there is only two different metal and two different light colors.

16.3 Identification of conceptual difficulties in Light and P.E.

PhET (Perkins et al., 2006; Wieman, et al., 2008) and other simulation researches (Baser, 2006; Jaakkola, Nurmi, & Veermans, 2011) supports that simulations are valuable in avoiding, identifying and remediation of conceptual errors. Some research has shown that preservice students also have similar misconceptions as their learners but not as frequent. This study shows that students seemed to have greater difficultly with the concept of stopping potentials, work function of a metal and interpreting the graphs in validating Einstein's explanations. The interviews with students with pseudonyms Bhengu, Hagy, Sipho and Aneel reflect their understandings-both correct and problematic areas in the P.E. Students were interviewed on their understanding of the graphs (Figures 3 and 4) that were obtained experimentally and were also used in the PhET simulation analysis.

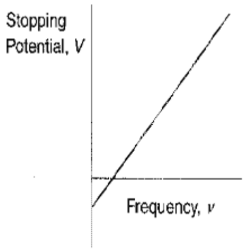


Figure 3: Stopping potential V vs f

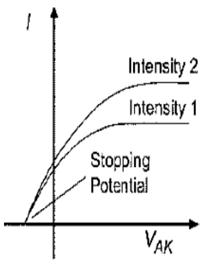


Figure 4.1: Current vs Intensity

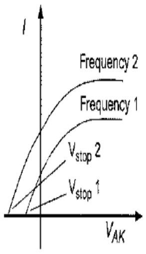


Figure 4.2 Current vs frequency

Interviewer: What you understand about the relationship between energy and frequency of light, from the graph obtained from the simulations and experiments (Figure 3)?

Bhengu: What I understand so far about the photoelectric effect, in terms of energy, we have the wave theory and the particle theory, the wave theory predicts that if the light that is used to shine the metal having a low frequency and with high intensity, the light could emit electrons in the metal but the frequency of the light does not affect the kinetic energy of the emitted electrons.

Interviewer: So you are referring to the frequency of light not affecting the kinetic energy of the electrons, where does this idea emerge? Can you remember the simulations that you did? Did you use different light colours of same intensity?

Bhengu: In the simulations what I have observed there is that when we are using blue light, more electrons were ejected, but when I decreased the frequency moving towards red light, no electrons were ejected. So I concluded that the frequency of light is directly proportional to kinetic energy.

Interviewer: What did you observe when the intensity of light was changed?

Bhengu: What I have seen is that intensity does not have that much effect on the kinetic energy of the emitted electrons. I used the same light and kept the frequency fixed and changed the intensity and try look at the emitted electrons. There was not much effect in the flow of electrons.

Interviewer: So what did the P.E. tell you about the nature of light?

Bhengu: It tells me that light can behave as a wave and it can also behave as a particle. When you use the frequency of light, that produces wave properties, then you see no electrons being ejected from the metal, this produces the wave properties. But when you use the same frequency with higher intensity then this produces particle properties. When there are no electrons coming out, that is a particle idea. In the wave theory, high intensity and low frequency, some electrons being ejected, But with the same, in the particle theory the electrons do not come off the metal. In the wave theory, electrons are released even though low frequency light is used but in the particle theory if the light is below the threshold frequency there will be no electrons being ejected.

Comment: Bhengu uses the word “could” suggesting that the wave theory predicts that light will not eject photoelectrons under certain conditions whereas in terms of P.E. all frequencies of light and intensities, given enough time would eventually eject photoelectrons. Also the frequency of light above threshold frequency does affect the kinetic energy as f α E_{k}. Bhengu also confuses the number of electrons with frequency, “blue light has more electrons” implying that red light has fewer for the same intensity. While he knows that blue light has a higher frequency than red light, he comes to the incorrect conclusion and shows a lack of understanding of work function of the metal and threshold frequency. Later on, he comes to the correct relationship (for cases above the threshold) with frequency of light and kinetic energy of the electrons. While he observed correctly the effect of intensity on the flow of charges, he could not come to a decisive relationship between intensity and number of electrons. We see in the last part of the interview he confuses the explanation of why the wave theory fails to predict observations of the P.E. while ascribing both wave and particle attributes to the P.E. Wave when electrons are ejected and particle when no electrons are ejected. He attempts to make some sense of P.E. but is still confused in interpreting the results of P.E.

Interviewer: What do you understand by stopping potentials?

Hagy: It’s the voltage needed … -2 V to stop electrons from the experiment and the current was zero.

Interviewer: What do the graph of V vs f conclude? Why does the slope cut the f axis? What does this mean?

Hagy: It means V proportional to f but on the x-axis, it means V=0 while f has a value.

Interviewer: What information does the graph of V vs I provide (Figure 4)? What do the 3 flat slopes indicate?

Hagy: The intensity is energy of light falling on the metal on the area …it’s just about the electrons. It was hard to picture that I (*current)* value of the simulation and I cannot explain it without understanding the theory of light. It’s a graph of Ohm’s Law.

Interviewer: Did you encounter any problems with the concepts of concepts of frequency and intensity?

Hagy: The difference between the intensity and frequency… I cannot make sense of. I don’t think I understood that. I know frequency and I know why I got the straight line but I still cannot explain the x-axis. Because we were dealing with the wave particle it was easy to see and correlate with the nature of light but when you come to the particle theory it was about photons and quantization. I understand a photon in general terms, packets of energy but I don’t go back and ask myself what is a packet of energy. With the theory that we have been doing I understand how we go from energy into matter but in real life I still do not understand how we go from energy to matter.

Comment: Hagy has some physical understanding of the practicals and of intensity but could only just read the information from the graph of V vs f and could not interpret the results in terms of theory of the photon light and could not differentiate between intensity and frequency of light. The graph (Figure 2) was looked upon as the familiar Ohm's Law. For Hagy, the concepts of photons and particle nature of light is far more difficult to understand than wave nature of light. Similarly, Sipho shows physical interpretation of the graphs and no link to the nature of light or the nature of the work function of the metal. He does not link V to W/Q and hence to the kinetic energy of the light photons.

Interviewer: What about the graph (Figure 3) you had, the first set was voltage vs frequency rather that energy vs frequency, was there an understanding why voltage rather than energy?

Sipho: The graphs show voltage not energy. It shows V proportional to f.

Interviewer: How do you interpret Graph 4 where light of different intensities were used?

Sipho: It was a slope graph curving to a point of equilibrium. As we shine more light in the metal because the graph is starting in a straight line first then curving to an equilibrium. It is like there is radiation so it is like you extract electrons and less electrons are left in the metal and less current is given out so the current comes to a point where it does not increase.

16.4 Fostering Collaboration

Students were encouraged to work in pairs and in groups. Students occasionally communicated with each other in their mother-tongue language isiZulu especially to explain difficult ideas and instructions to other students.

6.5 Developing Pedagogic Content Knowledge (PCK) of preservice students and role of instructor

As Roth's (1995) study emphasized that student' interactions with a teacher rather than the software itself promoted student learning, preservice teachers were encouraged to reflect on how they were engaging on the P.E. PhET learning tasks as well as when and how they interact with their peers and instructor. No guidance was given as to the way they approached the problem solving tasks but they were encouraged to interact with their peers and dialogue about concepts that they felt uncertain of. The interviews recorded show that students indicated that PhET simulations will save time in class but they also concur that the development of real-life laboratory skills and acquiring technical expertise are primary experiences to develop physics teacher's skills.

Interviewer: Is PhET simulation first better than laboratory work?

Hagy: We must do laboratory work first and then perform the simulation.

Aneel: Yes. It takes too much time in the laboratory. I would like to start with the simulation, followed by the theory then lastly I will do the actual experiment.

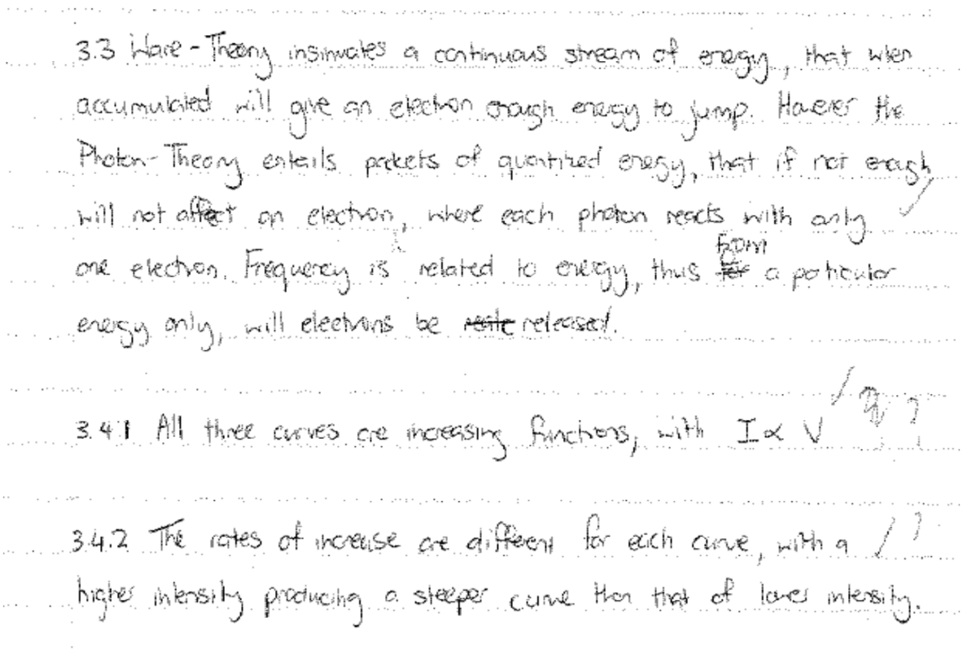
Interviewer: What about learners' real-life experiences?

Bhengu: Learners must do real demonstration but learners using simulations can then see the current flowing. It does not make sense to the learners if laboratory work is not introduced first. For new learners they need this…experiments … for real life.

> Sipho: I would start with the simulation, Explore the simulation, ask the learners questions. Try and challenge the learners without doing any theory because it will help them to think, then I would do the theory try to link the theory with the simulation, then maybe they can be in good position to use the apparatus and the actual apparatus can also be used to correct the misconceptions of the simulations like the idea of number and energy of the electrons that is embedded with the simulation, everybody knows that we cannot visualize individual electrons but it good to see in simulations.

17. Discussion

Arons (1997) notes that "The clear and intelligible to the quantum concept is through the photoelectric effect" (p. 285) and add that many unfortunately, abbreviate the story to the point where students memorize the end results without understanding. We have seen in the case of Bhengu who did little practical work but did the simulation in detail, the kinds of confusion arising from a lack of in-depth practical work. Arons (1997) advocates a start with Phillip Lenard's experimental work which is similar to the current experimental set-up but essential to start with the schematic diagram of the apparatus (like Figure 2) and this provides some experience in interpreting the electrical circuit and offers a 'valuable pedagogical opportunity" (Arons, 1997, p. 286). Concepts of 'retarding" or negative potential difference and "accelerating" or positive potential difference between the plates can be developed as the diagram allows opportunity to think about what it does and how the ejected electrons will behave. The graphs of saturation current for varying intensities and current for varying frequencies (Figure 4) posed serious difficulty for students to understand and to conclude that the maximum (saturation) photocurrent under accelerating potential difference was directly proportional to the intensity (energy/unit area/second) of incident light of the same wavelength of monochromatic light. Most difficulty was encountered in interpreting the graphs of the retarding (stopping) potential difference of Figure 4 which indicates the kinetic energy of the electrons. The ΔV_s is independent of light intensity but depends on the wavelength and cathode material. When the ΔV_s was increased, reaching -2V, the photocurrent was zero. ΔV_s is called the "stopping potential difference" and is unaffected by the intensity of the incident light. The surprise was that the stopping potential only altered when light of different frequency was used or a different metal cathode. Students should be encouraged to predict prior to the results and to postulate explanations before teachers' input. For example, it was expected that for any intensity and frequency photoelectrons would be ejected but this did not occur in the P.E.! Since concepts in Light are abstract, students often develop memorized answers, a range of alternative conceptions and poor graphical analysis related to wave and particle theory of light. Hagy, a bright student, explanations of P.E. (Figure 5) and interpretation of the graphs (Figure 3 and 4) in her final examination paper shows the extent of the problem.



3.3 Wave-Theory insinuates a continuous stream of energy, that when accumulated will give an electron enough energy to jump. However the Photon-Theory entails packets of quantized energy, that if not enough will not affect an electron, where each photon reacts with only one electron. Frequency is related to energy, thus ~~for~~ from a particular energy only, will electrons be ~~rele~~ released.

3.4.1 All three curves are increasing functions, with I ∝ V ?

3.4.2 The rates of increase are different for each curve, with a higher intensity producing a steeper curve than that of lower intensity. ?

Research has shown that these alternative conceptions are common to both learners and teachers. However, there is considerable evidence that PhET interactive simulations can be powerful tools for achieving student learning of science (Wieman, et al., 2008). Recent research conducted with PhET Interactive simulations focused on the specific aspects of simulations that help students build a conceptual understanding of the science; specifically the value of showing the invisible, the use of analogy and effective levels of guidance with simulations, while the nature of peer interaction and mentor guidance influences the amount of student engagement (Cleavesa & Toplisb, 2008). McKagan et al. (2008) found that simulation-led iinstruction leads to more and better student mastery of the P.E. than traditional instruction but some students are less successful in drawing a clear logical connection between the observations and inferences of the P.E.

18. Conclusion

The preservice students did not need much guidance in using the design features (technology) of the PhET simulations but required individual support and clarity on concepts such as stopping potentials, interpretation of V-I graphs and solving more complex problems. Some student's conceptual difficulties were more readily 'observable' with the PhET simulations and inquiry interviews. Students who had language and conceptual difficulties sought help by partnering voluntarily with peers to share their understandings. The preservice students were also aware of the limitations of simulations and how and when to use them appropriately in learning and teaching of Light and P.E. Most of the preservice students in this study advocated developing laboratory experience later, after simulations. The study showed that while some students improved their understanding of P.E., most initially held shallow and memorized ideas of the results, experimental procedures and photon conception acquired through fast-pace theoretical lectures, laboratory and simulations but post-data from examination papers revealed improved understandings of the observations and explanations of the P.E. However, poor inferences from the graphs suggest that graphical analysis, critical engaging interviews and further thinking and reflections are necessary for deeper scientific connections to be made.

19. Implications

The study suggest that in spite of lectures, simulations and practical work within time constraints, some students do find the abstract nature of concepts, relationships (in Einstein's explanations) and graphs difficult to interpret and hence a variety of strategies, resources and techniques are needed to cater for the diversity of student background skills and cognitive abilities. Arons (1997) adds that it will take several encounters for many students to master these abstract concepts. Integrating ICT simulations with formal practical work, building basic conceptual knowledge, interviews, and conceptual questions through examining the historical development of P.E. in developing a thorough understanding of the nature of Light can support effective learning in this regard.

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