THE USE OF I.C.T. IN THE TEACHING OF KINEMATICS AT POST-SECONDARY LEVEL – A CASE STUDY

Charles Bonello

ABSTRACT
This paper is meant to probe into the effectiveness of I.C.T. as a teaching resource. An experimental method was adopted as the research design of this study and two groups of students i.e. a test and a control group participated. The students were college students (16-18 year olds) who were studying Physics at Intermediate level.
All students did a pre-test in order to establish equivalence of groups and to identify the different misconceptions that they have in the area under study - Kinematics. Two course layouts were designed for the test and control group. The test group was taught using simulations and video graphing as a teaching aid. The control group were taught using the lecture method and some simple demonstrations. Both courses ran parallel and addressed the misconceptions identified.
A post-test was carried out to check for differences in achievements between the groups. Analysis of the results provided the raw material to identify how effective was the use of I.C.T. as a resource in the teaching of kinematics. The paper tries to identify the possible reasons for these results.

KEYWORDS
education, I.C.T., kinematics, misconceptions, physics

INTRODUCTION

When students come to a post-secondary school they still seem to be struggling to understand fundamental concepts in physics. I.C.T. is often cited as a panacea for solving educational problems but evidence on the use of computers in a variety of situations suggests that the results may not be uniformly satisfactory. This study will consider whether I.C.T. can successfully be used to teach basic physics concepts to students participating in a course in kinematics at post-secondary level. The aim is to review the unit taught for the Intermediate Matriculation Physics examination and restructure it so as to use I.C.T. during the course work.

Similar work on this area was done by researchers including Beichner (1990); Hennessy et al., (1995) and Thorton & Sokoloff (1990). Their results were inconclusive. On one hand, some studies showed that the learning of certain concepts in physics could be significantly improved using the microcomputer-based labs (MBL's). In fact an evaluation revealed that MBL's proved significantly more successful than the traditional problem-solving laboratory sessions (Brasell, 1990). On the other hand when an interactive video was used as an I.C.T. resource slight improvements were registered (Beichner, 1990). Thus it seems that the I.C.T. resource characteristics are crucial in determining the possibility of effective learning. This is only one of the many variables that one meets with when trying to enhance learning using I.C.T.
Research regarding learner control suggested " learner control is most effective when students have some expertise in the content area, are trained in the use of learner control, possess high aptitude and high inquiry, and are unlikely to skip important material or quit the lesson prematurely" (Cronin, M., & Cronin, K., 1992, p.39). On the other hand several theorists have identified theoretical and empirically

based reservations regarding the pedagogical benefits of learner control of instruction. Students "may not be the best judges of what instruction they need, how much instruction (they need), when to seek instruction and what to attend to in an instructional segment" (Canelos *et al.*, 1986, as cited in Cronin, M., & Cronin, K., 1992, p.39)

A supposition that is made whenever I.C.T. is used as a teaching resource is that humans appear to be particularly adept visual learners (Kobayashi quoted in Rieber, L., & Kini, A., 1991). This statement is backed by a dominant theoretical explanation i.e 'the dual-coding theory' (Paivio quoted in Rieber, L., & Kini, A., 1991). This theory suggests that there are independent encoding mechanisms, one visual and one verbal. It contends that pictures and words activate independent visual and verbal codes and makes several assumptions.

The first is that separate coding mechanisms are additive, so that something coded in both visual (computer screen) and verbal (worksheet) forms is more likely to be remembered. In this case study therefore, as the experimental group was subject to both visual and verbal codes it should have had an edge on the control group, at least as far as recall is concerned. A second assumption is that these two coding mechanisms differ in that a picture is more likely to be coded verbally and pictorially than words. Thus the probability of recall is increased due to the availability of two mental representations instead of just one. (Reiber, 1991) This becomes relevant in teaching when the content cannot be translated into an image. Here dual coding is less likely to occur. Concrete concepts like "man" or "chair' are good examples of information which readily produces internal images in most people. Conversely, people do not automatically form internal images of abstract concepts like "vectors". In these cases, it is often useful to provide the learner with an image that communicates the most salient features of the concept. This can be done with I.C.T.

HYPOTHESES

The research was based on evidence of past research. It was hypothesised that:

1. The students using I.C.T. in their course work will more likely fare better in understanding the basic physics concepts presented to them than will the students who would have attended the traditional type of course.

2. The experimental group will also be able to use the concepts learnt more readily in other contexts than the control group. Application of basic physics to a number of different situations occurs more readily with students using I.C.T.

DESIGN OF THE INVESTIGATION

The investigation was carried out at the University of Malta, Junior College. This is a pre-university institution with a total population of around two thousand five hundred 16-18 year-old students. The study was conducted with students taking Physics at Intermediate level i.e. a level that can be described as between advanced and ordinary level. All these students have obtained at least a grade 5 in their Secondary Education Certificate (SEC) in Physics. The course commitment was a one-hour lecture per week.

In the design of this research work, two groups were set up. The experimental group that was to cover the course work using I.C.T. and the control group that was to cover the work using the conventional method of teaching and learning. Both groups were given a pre-test and a post-test on Kinematics.

Randomisation came about naturally since the way students are assigned to different classes at the Junior College is not tied to some form of selection and classes have mixed ability students. The experimental and control groups were each made up of such classes. Although the students were randomly assigned in different classes there was the possibility that when grouping classes together, the control or the experimental group would end up with a bias such as gender bias. Thus other variables would be introduced that are likely to affect the scores on the dependent variable.

In order to minimise this effect, groups were matched. Matching was done as much as practically possible in the following areas: group size, gender, Secondary Education Certificate (SEC) grade in Physics (refer to Table 1 below), experience with computers and choice of subjects (Cohen L., & Manion L., 1992, p.197). In order to do this exercise, some background information was gathered from the students.

Table 1. Experimental and control groups and students' SEC grade distribution

SEC Grade ⇒	**1**	**2**	**3**	**4**	**5**	**6**	**Number of students**
Test Group	6	7	12	22	1	0	48 (M:20,F:28)
Control Group	4	7	13	23	3	0	50 (M:18,F:32)

SEC = Secondary Education Certificate, M = male, F = female.

THE PRE-TEST DESIGN

In order to ensure the content validity of the test, a list of specific objectives for the whole topic was made. Test items were then selected, so that the whole topic was well represented. Besides, four colleagues also teaching Kinematics reviewed this test. Their comments suggesting some improvements to the test were noted and the necessary changes made.

The one-hour pre-test on 'Kinematics' was split up in two sections. Section A had fifteen multiple-choice questions and section B had three short questions. The test was then administered to all six classes during the same week. The tests followed the planned schedule, so by the end of the week all pre-tests were gathered. After marking the tests, an item analysis followed and a listing of the misconceptions emerging from the test was drawn up.

ANALYSIS OF PRE-TEST RESULTS

The test provided a check for statistically significant differences in the way students from test and control groups gave right or wrong answers. It was used as a means of identifying specific differences between groups in the subject Kinematics.

Distractors were deliberately selected so as to attract students to previously reported common errors (Beichner 1994; McDermott *et al.,* 1986; Millar & Kragh, 1994; Twigger et al. 1994). They also reflected common errors made by students taking Kinematics. The distractor analysis was meant to help in bringing out the problems students had when following such an area of study. This study revealed that both experimental and control groups had a wide variety of vague ideas about motion based on intuition, experience and their perception of previous learning experiences in their O-Level course work. The distractor analysis for the groups confirmed that control and test groups had the same difficulties in this area.

IMPLICATIONS FOR COURSE WORK

A low score in the physics diagnostic test administered does not mean simply that the basic concepts of mechanics are not understood, it means that alternative misconceptions about mechanics are firmly in place (Halloun I., & Hestenes D., 1985). Thus, in planning the course work for the teaching of kinematics, both for test and control groups, the nature of the students' prior concepts had to be considered. As a result of this test a number of key reconstructions were identified. Instructional materials, including the I.C.T. activities prepared in the course work, focused on the reconstructions listed.

Table 2. Main reconstructions in teaching kinematics

STUDENTS' CONCEPTIONS	GOAL CONCEPTIONS
1. One does not need to select a particular time interval when considering a body which is accelerating i.e. one does not have to consider the time interval during which the acceleration takes place.	It is essential that any calculation of acceleration considers only the time during which the acceleration took place.
2. Equations for constant velocity and constant acceleration can be used interchangeably.	Equations of motion have to be used keeping in mind the type of motion being presented i.e. uniform velocity or uniform acceleration.
3. The vector nature (size and direction) of a physical quantity can be ignored as it does not really affect the real life situation	Vectors have a size and direction. Both must be taken into account when working out the solution of a problem with quantities that are vectors
4. The area under a graph this is necessarily a measure of 'distance'.	The significance of the area under a motion graph can be elicited from the axes of the graph.
5. When considering the gradients of graphs it is not essential to consider the type of graph axes being considered in order to interpret / compare / calculate gradients.	An awareness of the different meanings that different graphs (s-t, v-t and a-t) express is to be considered before eliciting information on graphs.
6. Heavier objects fall faster than objects, which are lighter, thus they reach the ground before lighter objects.	All objects fall to the ground with the same acceleration. Thus they reach the ground at the same time, unless there is a retarding force acting (e.g. air resistance).

7. In projectile motion the horizontal and vertical motions need not be considered as independent.	Analysis of projectile motion of a body requires a treatment whereby one considers the horizontal motion of the body as constant velocity and its vertical motion as acceleration.
8. Concepts like 'decreasing acceleration' and 'deceleration' are similar.	'Decreasing acceleration' implies that the velocity is increasing with time but at a slower rate, while 'deceleration' implies that the velocity is decreasing.

COURSE WORK DESCRIPTION

After considering these misconceptions, the unit 'Kinematics' was planned and a time frame set. For the experimental group, these sessions included an introductory session and four sessions using six Interactive Physics simulations and video graphing exercises taken from Cambridge Multimedia Motion. All these sessions were done in the computer laboratory. Throughout these sessions all students had a computer each so they could work at their own pace. This did not hinder a number of informal exchanges or students helping each other out when the occasion arose.

The control group had a similar time frame and scheme but now all sessions were done in a lecture room. In this case, the motion being studied was aided by real visual representation. Thus, if an example considered a ball thrown vertically upwards - a ball was taken to the class and thrown vertically upwards. Students engaged in active discussion as they worked through their worksheets.

SOFTWARE AND WORKSHEETS

The main software package used throughout the course was *Interactive Physics* Player Workbook written by Cindy Schwarz for Knowledge Revolution. This consists of a software package having a set of forty simulations that cover quite an extensive range of the Mechanics syllabus at Intermediate level and a workbook accompanying the software. The simulation worksheets of the experimental group were adapted to focus on the Intermediate Physics coursework.

The worksheets given to the control group were designed for class discussion purposes and were complimented with class demos. These covered the same coursework as the simulation worksheets. The presentation of the sheets was also similar to that of the simulation sheets.

Another software package that was used in the course was the Cambridge Multimedia Motion produced by Cambridge Science Media 1996. This CD-ROM had some fifty-four sequences of moving subjects on the disc. Relevant to the course work were the sequences showing the 'hammer and feather experiment on earth' and the 'moon and projectile' motion. This software was used as a demonstration. No direct student interaction was possible in this case.

THE POST-TEST DESIGN

The one-hour post-test on Kinematics was administered to all six classes during the final week of the course. After correcting the tests, an item analysis and a comparative study of pre-test and post-test scores was made.

In order to probe deeper into the effect that computers as a teaching resource had on the students, a set of six informal interviews were made with the participants. These students were selected on the basis of the gain in their test scores. Three of the students had obtained an improved post-test score while the other three obtained a lower post-test score.

ANALYSIS OF POST-TEST RESULTS

The test had two main aims. The first was to check whether the experimental and control groups had obtained mean scores that were significantly different from each other. This would imply that the use of I.C.T. with the experimental group had made a difference in the way the students learned kinematics. Besides it was meant to check whether the use of I.C.T. enhances particular areas of the topic, such as graph interpretation. The t-test for independent samples was performed on the different groups mean scores and these results were obtained.

Table 3. t-test for differences between means in post-test scores of test and control groups.

Variable	No. of Cases	Post-test scores mean	S.D.	SE of Mean
Test Group	42	61.6	13.7	2.12
Control Group	49	62.1	15.4	2.20

t = -0.160	df = 89	p = 0.874

The results indicate that although the control group seem to have obtained a higher mean score in the post-test, the difference was not statistically significant. This result confirmed that no group ended as significantly better in Kinematics after the course work was concluded.

COMPARATIVE ANALYSIS OF PRE AND POST-TEST RESULTS

The analysis considered the post-test scores and the gain in scores of participants. The question posed here was " Is the post-test score and the gain in scores of one of the groups significantly different than that of the other?". The table below gives the mean value of the pre-test score, post- test score and gain for the two participating groups.

Table 4. Mean scores and gain for test and control groups

Variable	No. of Cases	Pre-test scores mean	SD of pre-test scores	Post-test scores mean	SD of post-test scores	Mean Gain	SD of gain
Test Group	42	56.4	14.7	61.6	13.7	5.2	11.5
Control Group	49	55.9	12.9	62.1	15.4	6.2	12.5

The results indicate that the students participating in the test group started off having a slightly higher average score than the control group. After the treatment, the control group seemed to have performed better in the post-test than students in the experimental group.

The two-tailed t-test for difference between means of independent samples was performed on the post-test scores and the gain.

Table 5. t-test for differences between means in post-test scores of test and control groups

t = - 0.160	**df = 89**	**p = 0.874**
t-test for difference between means in 'gain' of test and control groups		
t = - 0.870	**df = 89**	**p = 0.387**

The above t-test results indicate that although both the control and the test group improved in their overall post-test score, none of the two groups did significantly better than the other in the post-test. This implies that none of the two treatments provided to the groups proved a more effective learning experience. The use of I.C.T. in the course work did not seem to improve the overall understanding of the students' knowledge of kinematics.

The above result leads to another reflection on the use of I.C.T. in education. "Can I.C.T. prove useful in the teaching of particular areas of the topic concerned?" In order to answer this question, an item analysis was performed on both pre-test and post-test items.

The analysis could be grouped under four main areas. The first area is the understanding and recall of basic terms such as velocity and acceleration. The second area is related to how students analyse and solve problems on linear motion and the third considered the process of eliciting information and interpreting motion graphs. The fourth area is the study of objects falling under gravity with particular reference to projectile motion. The results of the test items grouped under the four main areas were analysed and a sample of these results will now be considered.

Motion graphs - In selecting a graph that relates to a text description or selecting a text description given a motion graph the results showed that both groups did better in the post-test responses but none did significantly better than the other. Again it seems to be that the simulations were not so effective in causing the conceptual shift in spite of the visual impact simulations were assumed to have on the students making use of I.C.T. for their course work.

Vector nature of physical quantities – By presenting the vectors as part of the screen layout, and showing how the vector changes in size and direction while the object moved, it seemed that most students in the test group were visually aided to keep in mind the vector property of the quantity. The control group on the other hand were presented with only white board drawings of the vectors. In the items related to the vector nature of the quantities velocity and acceleration, the control group seems to have had the edge over the test group in the responses given. Considering the initially stated fact this was rather surprising.

Projectiles - The projectile items proved unexpectedly difficult for both groups. The mark obtained in the post-test by the groups was a slight improvement on their pre-test score. The test group obtained a relatively higher gain than the control group.

Throughout the course work, the worksheets emphasised the type of motion exhibited in the vertical and horizontal direction. In the simulations, the students in the test group were aided by the visual representation of a ball's projectile motion together with the vectors for horizontal and vertical velocities. During the ball's motion on the screen, the students followed the different ways in which the two velocity vectors were changing. The control group on the other hand, were shown on the white board diagrams of the way the vectors were changing, but this representation was static. Being a new topic, students' work on projectile motion proved to be conceptually very demanding and probably that is the reason for the low gain.

THE COURSE - A CRITICAL PERSPECTIVE

This study investigated the educational impact of the visual juxtaposition on computer of motion events accompanied by either motion graphs or with symbolic representations (e.g. an arrow) of an abstract concept (e.g. a vector). The main hypothesis stated that watching a recreation of the motion event in the form of a computer animation together with the motion graph or symbolic representation should be sufficient to help students learn about Kinematics significantly more than by the traditional lecture method. This did not prove to be the case as not only was there no significant difference between groups post-test scores ($t = -0.160$, $df = 89$, $p = 0.500$) and gain ($t = -0.87$, $df = 89$, $p = 0.914$) but the test group students had slightly lower post-test scores than the control group students. These results merit a proper critique of the methodology of the course and discuss possible reasons that could have contributed to the results stated above. Besides evaluating the practical aspects of the course, it considers also the case study from a theoretical viewpoint.

I.T. USE - SOME THEORETICAL CONSIDERATIONS

These considerations complement practical insights gained throughout the course work and give a more complete picture of the factors that make I.C.T. effective in the teaching context. Besides, they are necessary if one is to come to some form of general conclusion on the inclusion of I.C.T. across the curriculum

The extend of I.C.T. use across the curriculum in Malta and the context in which I.C.T. is used by students helps to place the interpretation of results in their proper perspective. The use of I.C.T. as a cross-curricular theme in the secondary schools had not come into effect by the time the students participating in the course were in their secondary school. This meant that the students participating in this course were in fact using I.C.T. as an aid to learning Physics for the first time.
An idea from the psychology of perception suggests that presenting the motion event on a computer screen besides the relevant variables (for example, a graph) help students make the cognitive linkages between the two (Beichner, 1995). In the course work, the software used considered two different types of cognitive linkages. The simulations of the software package Interactive Physics linked computer animation with vectors and graphs, the C.D. multimedia motion linked videos with motion graphs.

Prior to probing deeper into the effectiveness of the software packages used, some factors need consideration. First, the initial stages of the perception of motion actually take place in the retina, they do not share general mental faculties like memory and attention. These stages are not greatly influenced by higher-level processes and because of this they are "cognitively impenetrable". Thus it is difficult to ignore something that is moving or somehow changing (Beichner, 1995). The software used was meant to take advantage of this attention-focusing mechanism to direct students' attention to important information such as graph shapes and vectors that change in size and direction. In the simulations provided, an arrow of varying size and direction was shown to represent the vector. This was only a symbolic representation and its effectiveness is of questionable value.

The control group were shown an arrow drawn on a white board to represent the vector. This leads to a main difference in the treatment given to both groups. In their presentation, the test group was introduced to a dynamic visual while the control group were always presented with the static visual. The dynamic visual is better at communicating ideas that involve changes over time because of its ability to represent motion, thereby reducing the level of abstraction of temporal ideas. This was confirmed in the interview sessions where responses given by students were consistent with these statements and most interviewees mentioned that a topic dealing with motion should be presented using moving objects.

The static visuals on the other hand represent at best, visual snapshots of ideas on motion. They are often accompanied by arrows in the hope of suggesting the motion attribute in static form. Control group participants had to consciously work to connect and integrate these snapshots into a meaningful display, whereas for test group participants the animation automatically triggered apparent motion.

The idea of vectors and graphs considered in this case study require that an idea changes over time and involve directional characteristics. This necessitates that the dynamic visual be put to use. The static visual, at best, can only hope to prompt learners to mentally construct motion and direction on their own. The dynamic visual on the other hand should make the cognitive task more concrete by providing motion and direction attributes directly to the learner (Rieber, L., & Kini, A.,1991). These ideas considered in isolation seem to indicate that I.C.T. offers a more effective mode of learning than the traditional mode but this does not tally with the findings obtained in this research. One reason for this is that the matter at hand is much more complex than it seems to be and presupposes a number of variables not just the abovementioned ones.

CONCLUSION AND RECOMMENDATIONS

The results that were obtained in this study as in any other study were subject extraneous variables over which one had little to no control. The fact that I.T. is still being introduced in the Maltese educational system at post secondary level, the fact that the software choice for this course work was limited and that the tutor had only two years experience teaching with I.C.T. are three of the factors that one can state. These undoubtedly affect the findings of the study and could have affected the end results had any one of them been different.

Other factors are surfacing about such research work that makes these research findings questionable. One such study (Berg, A., & Smith, P., 1994) questions the way that the students participating in such studies are being assessed. The authors show concern about the instrumentation used to assess I.C.T. in teaching. They not only question the use of multiple-choice items but also state that free-response instruments would give significantly different results than those given by multiple-choice items.

Considering this latter point one cannot but recommend that the instrumentation for such studies be standardized. This could help to establish the findings of such studies on more solid ground. A recent study (McNeil, B., & Nelson, K., 1991) indicates that other areas in this field of research needs some form of standardizing. The degree of learner control, type of instruction (group or individual), type of software used and for what is it put to use (i.e. revision or to replace traditional teaching) all seem to affect the educational outcomes of such studies. Besides these, it would be interesting to conduct a similar study and assess retention and learning of concepts over a long period of time after the end of the experiment. Only by delving into such issues can we come to obtain a wider and clearer view of how to use I.C.T. effectively in our teaching.

REFERENCES

Beichner, R. (1990). The effect of Simultaneous Motion Presentation and Graph Generation in a Kinematics Lab. Journal of Research in Science Teaching, 27 (8), 803-815.

Beichner, R. (1994). Testing Student Interpretation of Kinematics Graphs. American Journal of Physics, (62), 750-762.

Beichner, R. (1995). Considering Perception and Cognition in the Design of an Instructional Software Package. Multimedia Tools and Applications,1,173-184.

Berg, A., & Smith, P. (1994). Assessing Students' Abilities to Construct and Interpret Line Graphs: Disparities between Multiple Choice and Free Response Instruments. Science Education, 78 (6), 527-554.

Brasell H. (1987) The Effect of Real-Time Laboratory Graphing on Learning Graphic Representations of Distance and Velocity, Journal of research in Science and Technology 24(4), p 385-395

Brungardt, J., & Zollman, D.(1995). Influence of Interactive Video Instruction Using Simultaneous-Time Analysis on Kinematics Graphing Skills of High School Physics Students. Journal of Research in Science Teaching, 32 (8), 855-869.

Cohen L., & Manion L. (1992) Research Methods in Education Routledge

Cronin, M., & Cronin, K.(1992). A Critical Analysis of the Theoretic Foundations of Interactive Video Instruction. Journal of Computer based Instruction,19 (2), 37-41.

Halloun I., & Hestenes D. (1985) The initial knowledge state of college physics students American Journal of Physics Vol: 53 pp. 1043-1055

Hennessy, S., Twigger, D., Driver, R., O'Shea, T., O'Malley, C.E., Byard,M., Draper, S., Hartley, R., Mohamed, R., & Scanlon E. (1995) A classroom intervention using a computer-augumented curriculum for mechanics. International Journal of Science Education,17 (2), 189-206.

McDermott L., Rosenquist M., & van Zee E. (1986) Students difficulties in connecting graphs and physics: Examples from Kinematics. American Journal of Physics Vol : 55 pp. 503 - 513

McNeil, B., & Nelson, K. (1991). Meta-Analysis of Interactive Video Instruction : A 10-year Review of Achievement Effects. Journal of Computer based Instruction,18 (1), 1-6.

Millar R., & Kragh W. (1994) Alternative frame works or context-specific reasoning ? Children's ideas about the motion of projectiles. School Science Review Vol:75 (272) pp. 27-34

Redish E. et al (1996) On the Effectiveness of Active-Engagement Microcomputer-Based Laboratories, Department of Physics, University of Maryland.

Rieber, L., & Kini, A.(1991). Theoretical Foundations of Instructional Applications of Computer-Generated Animated Visuals. Journal of Computer-Based Instruction ,18 (3),
83-88.

Russell T. (1995) IT in education - where have we gone wrong ? , Computereducation No 81.

Thornton R.K. & Sokoloff D.R.(1990) Learning motion concepts using real-time micro computer-based laboratory tools, American Journal of Physics No:58 p.858-867

Twigger D., Byard M., Driver R., Draper S., Hartley R., Hennessy S., Ramzan M., O'Malley C., O'Shea T., Scanlon E., (1994) The concept of force and motion of students between 10 and 15 years: an interview study designed to guide instruction International Journal of Science Education Vol. 16, No 2 pp. 215-229

C.Bonello
Asst. Lecturer
Physics Department,
Junior College,
University of Malta,
Msida, Malta
Email: charles.bonello@um.edu.mt