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An evaluation of curriculum changes in engineering graphics

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Abstract

The presentation of technical information graphically through the use of sketches, mechanical drawings, and CAD systems is a fundamental part of engineering practice. Differences in background experience and gender cause many individuals to possess impaired ability to spatially visualise solutions to problems. However, these abilities can be developed and enhanced through both formal educational and informal experiences. The development and integration of a computer-based visualisation course was initiated at RMIT in the 1992 as part of departmental educational effort to advance engineering graphics instruction. The problem of determining the effectiveness of various engineering graphics educational aids in developing students' spatial abilities was addressed in a research project that started in 1993.

The paper discusses the research project, presents findings from the study, reviews the engineering graphics course offered to all first year engineering students in 1993 and 1994, and recommends future developments.

Introduction

The development of a computer aided visualisation course in late 1992 initiated a process of change in the engineering graphics curriculum at RMIT.

Introducing new technology and new techniques of computer graphics in an engineering graphics course assumes that students are not learning just engineering graphics fundamentals but the CAD principles as well. The offered engineering graphics instruction should not lose sight of fundamental educational objectives. The integration of advanced computer technology in the engineering graphics education should not be a simple introduction to computer software or solid modelling. The improvement of visual geometric reasoning is the challenge educators need to confront with the computer graphics techniques and advance technology learning.

Engineering graphics and design educators have argued that instructional approaches should be developed such that students enhance their spatial abilities (Bertoline, Miller, Ezaki et al.). Miller claimed that students not given opportunity to develop spatial abilities may abandon their quest to become

engineers or fail to achieve their potential as practising engineers.

Differences in background experience and gender cause many individuals to possess impaired ability to spatially visualise solutions to problems (Miller, Suzuki et al, Lowenfeld). Two different learning strategies have been identified. The visual learning approach is characterised by reliance on visual imaging. The haptic learning strategy relies on additional cues provided by touch or movement. Lowenfeld found that one quarter of human population have a haptic approach in learning and are not able to rapidly and almost intuitively visualise correctly different object views, or to visually perceive transformations from 3D to 2D and vice-versa. Therefore, an engineering graphics educator must question how an instructional program can be designed and a media used to enable students to develop their spatial abilities.

To evaluate the effectiveness of methods used and to provide a formative and summative evaluation of the teaching and learning program, all groups of engineering students that have been learning Engineering Graphics Fundamentals were tested by the visualisation ability test at the beginning and at the end of

the 13 weeks' course. This evaluation method as well as recommendations for further development resulted from this study are presented in the paper.

Purpose of the Study

The purpose of the study was to evaluate the effectiveness of used instructional methods in developing student's spatial abilities.

Hypotheses of the Study

The following research hypotheses for the study were tested at significance level $\alpha=0.05$:

1. The used instructional methods significantly increased spatial abilities of students.
2. The psychological test results used for spatial ability measurements correlate closely with students' performance in the subject.
3. There is no falling off in students' mastery of subject content when they were instructed by new instructional methods.

Instructional Setting

Four engineering graphics instructional sets were created and combined in three groups of two. A two hour per week course that consisted of a one-hour computer aided lecture and a one-hour sketching based lecture was offered to all first year students in the first semester of 1993 and 1994 academic years.

The instructional sets used in the Engineering Graphics course are illustrated in figure 1.

During the first semester of 1992 only traditional engineering graphics set was taught, and the term end performance test results were used for comparison with the performance test results from the first semester of 1993 and 1994.

The abbreviations that match course codes have the following meanings:

ME104 class - Computer Aided Drafting (hereafter CAD) + Traditional Engineering Graphics instructional sets.

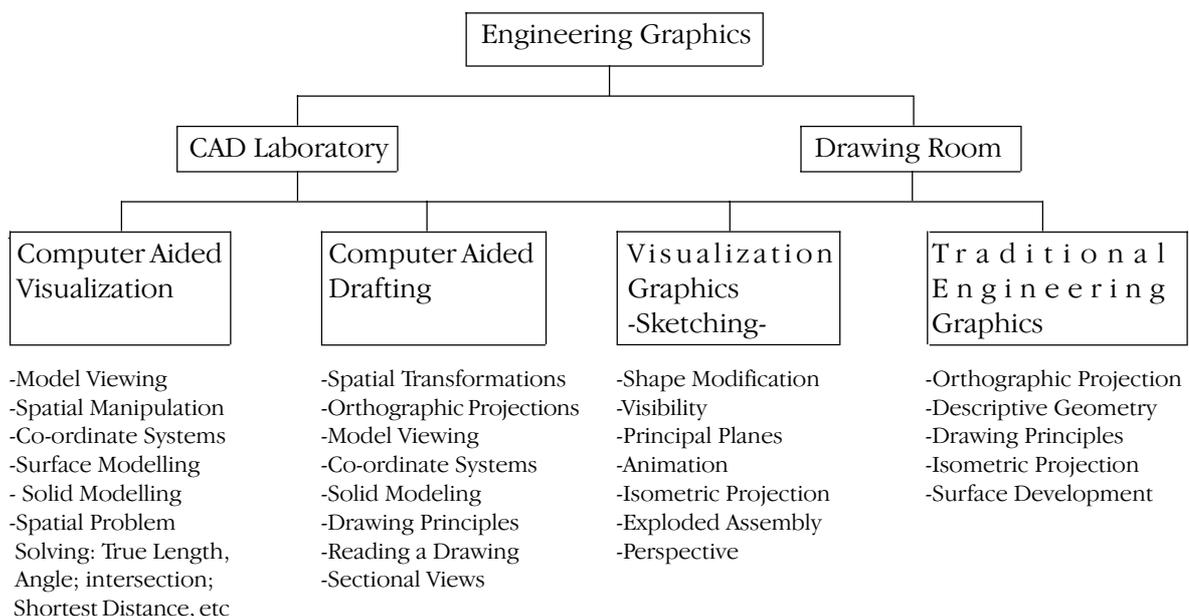
ME121 class - Computer Aided Visualisation (hereafter CAV) + Sketching Visualisation instructional sets.

MP108/103 classes - CAV + Traditional Engineering Graphics instructional sets.

Method

The entire population of Engineering Graphics students was administered the Mental Cutting Test (hereafter MCT) during the first and last week of the first semester in 1993 and 1994. Hereafter, the test that was given prior to the course is named 'pre-test' and after the course 'post-test'. The MCT was first developed for a university entrance examination in USA. As object recognition, object cutting and section rotations are necessary to solve the MCT it is particularly suited to evaluate the spatial abilities (Suzuki et al).

Fig. 1 Instructional Sets



Selection of the Sample

In 1993 the sample of 101 first year engineering students enrolled in the Engineering Graphics course at RMIT city campus was selected. The first group of 33 students was from ME104 class, the second group of 23 students was from ME121 class, and the third group of 45 students were from MP108/103 classes.

In 1994 the sample of 69 first year engineering students enrolled in the Engineering Graphics course at RMIT city campus was selected. First group of 36 students was from ME104 class and the second group of 33 students was from ME121 class.

Throughout the semester all students received the same amount of time in the class sessions. The difference between the groups was the instruction, the instructor and the time during the day in which the sessions were held.

Research Design

The main objectives of the study were:

- to determine the effects of instructional treatment upon the spatial ability of the students and
- to determine if the measured spatial abilities correlate with the students' performance in the subject.

To determine if the instructional treatment significantly affected students' spatial abilities and if significant difference occurred in spatial ability development of students from different class groups a one-factor analysis of variance - ANOVA method was used. Also for testing the third study hypothesis of no falling off in students' mastery of subject content when instructed by new instructional methods the same statistical method was used. In general, the ANOVA method requires the null and alternative hypothesis to be defined. In the figures 2 and 3 the null hypothesis is labelled as H_0 and alternative as H_1 . The question on which the ANOVA method is giving the answer is whether the difference among the sample means of the groups (pre-test-post-test; class groups; term end tests) are large enough to lead to the conclusion that the population means differ; or, alternatively, that the sample differences can reasonably be explained by random variation. The decision rule is to reject

the null hypothesis of no difference between the groups if at the significance level of 0.05 (for educational testing) the calculated F distribution is greater than its critical value selected upon degree of freedom for the sample. In the figures 2 and 3 the calculated F distribution is given as F and the critical value is given as $F_{c-1, n-c}$, where the $c-1$ and $n-c$ are degrees of freedom for the sample. So that if the $F > F_{c-1, n-c}$ the null hypothesis H_0 of no difference between the groups is rejected.

To determine the correlation between the students' spatial abilities and abilities in mastering the subject content the Pearson product-moment correlation coefficient was used. If the calculated correlation coefficient is greater than its critical value there is a considerable correlation between the groups. In the fields of psychology and pedagogy a coefficient of correlation may be simple interpreted as shown in table 1. In the figures 2 and 3 calculated correlation coefficient is given as C and its critical value as C_v .

Table 1.

| Coefficient of correlation | Correlation |
|----------------------------|--------------|
| +0.00~+0.20 | Little |
| +0.20~+0.40 | Low |
| +0.40~+0.70 | Considerable |
| +0.70~+1.00 | High |

Results of the Study

1993 Test Data

The following 1993 test data sets were analysed:

(I) The first set of data that investigated whether instructional sets (ME104, ME121 and MP108/103 class groups) affected students' spatial abilities was divided into two sections.

1) The first section analysed the pre-test and the post-test scores of the MCT using one-factor ANOVA to determine if there was significant improvement of students' spatial abilities caused by instructional treatment.

The ANOVA suggested that there is significant improvement of students' spatial abilities measured by the MCT for all three class groups. Because the F distribution for all class groups is larger than the critical value, the null

hypothesis of no improvement in the students' spatial abilities was rejected (See Figure 2. Section 1)).

2) The second section analysed the post-test scores of the MCT using one-factor ANOVA to determine if there was significant difference in spatial ability improvements of students from different class groups.

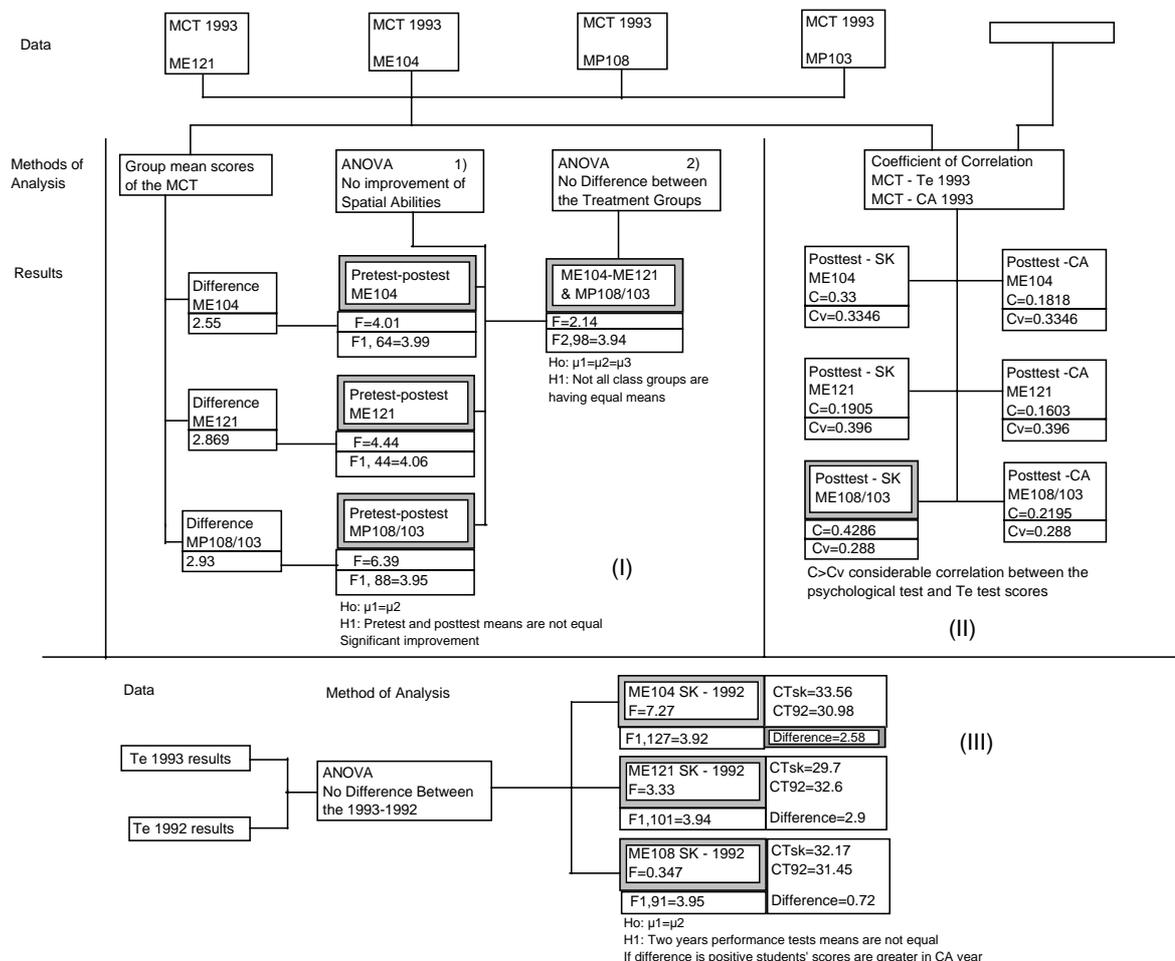
The ANOVA results showed that there is no significant difference between any of three class groups. Since $F=2.14 < F_{2,98}=3.94$, the conclusion was to not reject the null hypothesis of no difference between the class groups (See Figure 2. Section 2)).

(II) The second data set was concerned with whether the students' spatial abilities evaluated by the MCT correlate with students' ability in

mastering the subject content.

The Pearson Product-moment correlation coefficient results are summarised in Figure 2. The coefficient of correlation indicates that there is low correlation between the scores of the MCT and the term end performance tests for all class groups except for the MP108/103 group. For this class group a considerable correlation between the scores of the MCT and the term end performance test was determined (See Figure 2. Part (II)).

(III) The one-factor ANOVA statistical technique was also used to determine if significant difference occurred between the scores of the students' term end performance tests from the 1993 and the 1992 academic years.



MCT- Mental Cutting Test CA - Computer Aided
Te -Term End CT - Central Tendency
Cv - Critical Value -Confirmed Targeted Values
F - F Distribution SK - Sketching

Figure 2 Methods And Results for Statistical Analysis of the 1993 MCT Data & the Term End Performance Test Data from 1993 and 1992

Because the F distribution for two class groups is less than the critical value, the null hypothesis of no difference between the scores of the two years' term end performance tests was not rejected (See Figure 2. Part (III)). However, the ANOVA results showed that there is significant difference between the scores of the two term end performance tests for the ME104 class group.

1994 test data

The following 1994 test data sets were analysed:

(I) The first set of data that investigated if the instructional sets affected students' spatial abilities was divided into two sections.

1) The first section analysed the pre-test and the post-test scores of the MCT using one-factor ANOVA to determine if there was significant improvement in students' spatial abilities caused by instructional treatment.

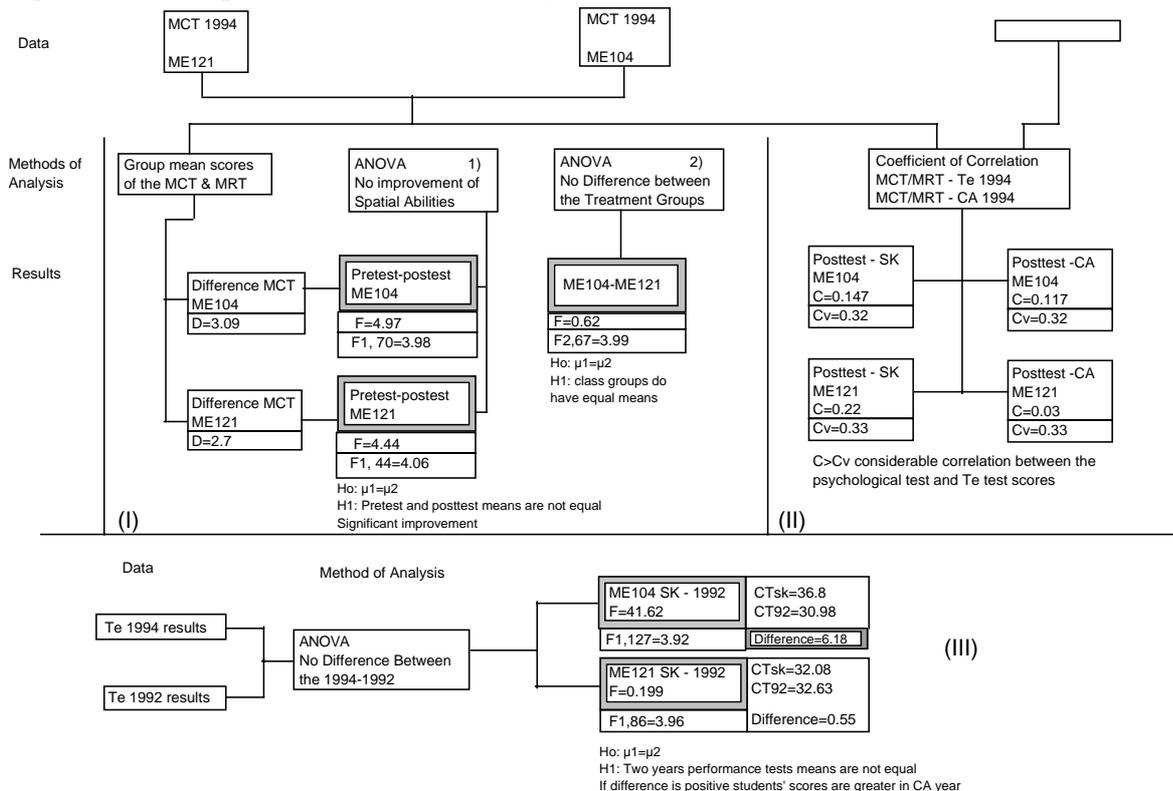
The ANOVA suggested that there is significant improvement in spatial abilities measured by

the MCT. Because the F distribution for two class groups was larger than the critical value, the null hypothesis of no improvements of students' spatial abilities was rejected (See Figure 3. Section 1)).

2) The second section analysed the post-test scores of the MCT using one-factor ANOVA to determine if there was significant difference in spatial ability improvements of students from different class groups.

The ANOVA results showed that there is no significant difference between the class groups. Since $F=0.62 < F_{1,67}=3.99$, the decision was to not reject the null hypothesis of no difference between the two class groups (See Figure 3. Section 2)).

(II) The second data set gathered in 1994 was concerned with whether the students' spatial abilities evaluated by the MCT correlate with their ability in mastering the subject content. The Pearson Product-moment correlation



MCT- Mental Cutting Test CA - Computer Aided
 Te -Term End CT - Central Tendency
 Cv - Critical Value Confirmed Targeted Values
 F - F Distribution SK - Sketching

Figure 3 Methods And Results for Statistical Analysis of the 1994 MCT Data & the Term End Performance Test Data from 1994 and 1992

coefficient results are summarised in Figure 3. Part (II). The coefficient of correlation indicates that there is low correlation between the scores of the MCT and the term end performance test for both class groups.

(III) The one-factor ANOVA statistical technique was also used to determine if significant difference occurred between the scores of students' term end performance tests gathered in the 1994 and the 1992 academic years.

Because the F distribution for ME121 class group is less than the critical value, the null hypothesis of no difference between the scores of the two term end performance tests was not rejected (See Figure 3. Part (III)).

However, the ANOVA results showed that there is significant difference between the scores of the two term end performance tests for the ME104 class group.

Discussion AND Recommendations

A taxonomy of the role of drawing in the graphics design process shows that 60% of abilities required for drawing are those that we call "visualisation" and is the prime target of the first year first semester undergraduate Engineering Visualisation course introduced in the department. The study that was undertaken to evaluate the effectiveness of used programs on students' "visualisation" improvements showed following:

- there was significant improvement of spatial abilities for all class groups in both years,
- the improvements in students' spatial ability was independent of the instructional set used,
- there was low correlation between the scores of the mental cutting post tests and the term end performance tests,
- there was no difference among the 1992 and the 1993 and 1994 term end test scores or the scores were higher in the years were the computer based course was introduced.

Recent Computer Aided Design systems facilitate production of drawings but the fact is that a designer still needs to visualise a three

dimensional object before s/he can produce an engineering drawing. The fundamental goal of engineering graphics education did not change with the introduction of new technology. The computer based course requires that the teaching of computer software and teaching visualisation is balanced so that the educational objective of improving visual reasoning is occupying the major part in the instructional set. The first result from the study conforms that the first year undergraduate Engineering Visualisation course significantly improves students' visual abilities.

The educational problem identified to be the enhancement of the student capacity to visualise spatial relationships was the core for Engineering Visualisation course development. The second result shows that developed instructional sets combined in the one and the two semester courses are all enhancing equally well those visual abilities.

The alarming finding in 1993 was the third result from the study. Further analyse of the test data shown by the graphs 1 to 5 of the post-test versus term end performance test scores, suggest that the "good visualisers" do not necessarily score high marks in term end test and vice versa. Contending that there are two different types of learning styles, the haptic and the visual style, and analysing the computer based course concept, at least two potential problems may be identified:

1. The individual learning styles were not matched by presented instructional set.
2. The visual types were not motivated; they already possessed advanced spatial abilities and they do not need the general visualisation instruction presented in the course.

It may be that some haptic individuals were helped by the computer aided part of the course and that they were able to overcome learning difficulties they usually had in handling the traditional sketching part of the course. It also may be that the "good visualisers" did not have the motivation to advance their learning in the subject.

The fourth result indicates that the new computer based course is helping the spatial ability developments at least for the haptic

type of learners. The advanced technology and computer graphics based engineering graphics instruction provides a more natural learning environment from the cognitive standpoint. The spatial manipulations in the computer 3D space having the potential to produce a learning experience of a type that helps haptics to develop their visualisation.

To develop computer aided engineering graphics instructional programs that match students' learning styles, the following two requirements should be satisfied:

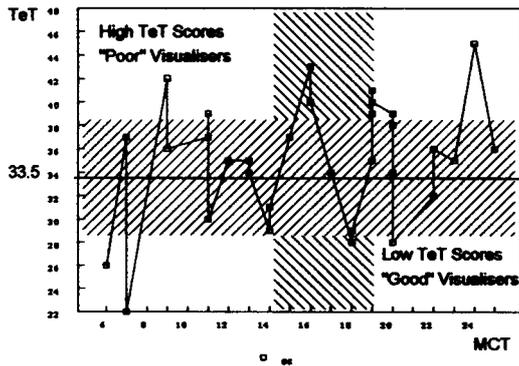
- Instructional programs must include basic spatial problems to help haptic individuals to develop necessary visualisation skills.
- For "good" visualisers more advanced and complex spatial problems should be offered.

The simple reflection of traditional engineering graphics techniques and teaching methods into a computer based instructional set is not producing a learning environment that is acceptable for all individuals with different learning approaches. The advanced technology and computer graphics techniques have the potential to enhance existing and introduce new instructional methods in engineering graphics. Creating computer based engineering graphics instruction that adequately employs computer graphics techniques and generates geometric methods that are challenging for both "good" and "bad" visualisers needs a theoretical base that is not paper-pencil orientated in the way that all present plane-projective techniques are. There is very little documented research in this field today even though computer graphics is now widely adopted in the higher educational system. To develop a teaching and learning engineering graphics program supported by advanced technology further research, based on a morphological analysis of computer based engineering graphics instructional approaches, needs to be undertaken. Some instructional distinctions from traditional descriptive geometry methods were introduced for the first time in the ME104 1994 class group. The difference between the pre-test and post-test group mean scores for this group was larger than for all the other groups in both years. This indicates the way ahead for research in the field of computer practice in engineering graphics to give enhanced outcomes.

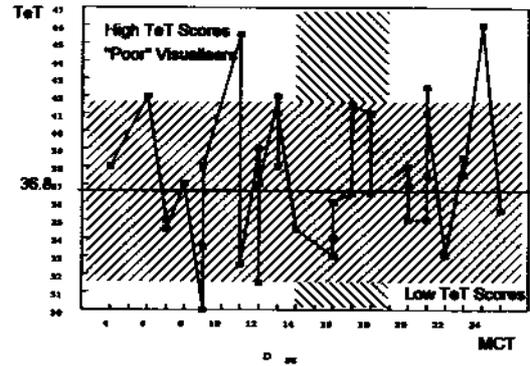
The research results from the present study are used here to establish a method for evaluating curriculum changes in engineering graphics, toward satisfaction of identified educational goal. Any instructional system should have a formal research base and be thoroughly tested before being implemented into widespread instructional use, and this paper defines the necessary procedure and criteria for that. All further methodological changes and research will be monitored by this procedure.

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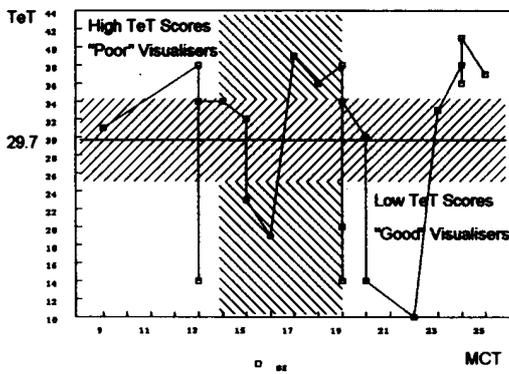
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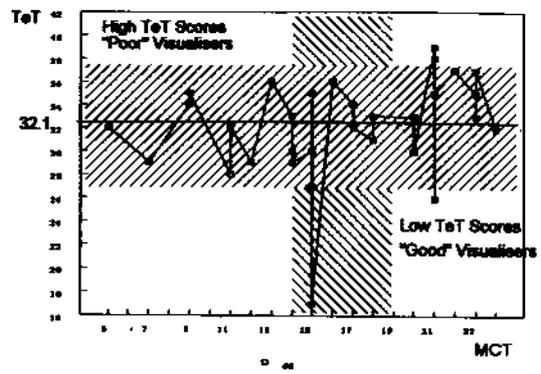
Graph 1 ME104 Posttest-SK 1993



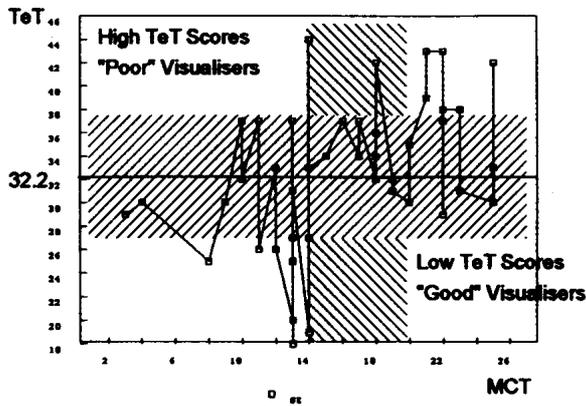
Graph 4 ME104 Posttest-SK 1994



Graph 2 ME121 Posttest-SK 1993



Graph 5 ME121 Posttest-SK 1994



Graph 3 MP108/103 Posttest-SK 93

Criteria used:

Unclassified learning style groups scored between 14 and 19 points on MCT:

≥ 14 & ≤ 19

A average term end test group scored central tendency ± 5 marks