MATHS FOR MAP USERS

Innes, L.M.

Department of Environmental and Geographical Science,
University of Cape Town, Private Bag Rondebosch, 7701, Republic of South Africa.

1. INTRODUCTION

Research into developing the spatial competence of high school learners has been in progress for some time (1). A number of research reports into the problems of school geography, including map use, have appeared during the last two decades. These have covered the perception of school geography held by black university students (2), problems associated with poor performance in relief mapwork (3), topographic map comprehension problems experienced by first year teacher training college students (4), the relationship between the standard of geography at high school and university (5) and the problems of teaching map use at university level to students who had very different levels of apartheid-style school education (6). Suggestions for dealing with the problems associated with teaching map use have included proposing an elementary model for teaching topographic map reading (7) and using a co-operative learning model to teach mapwork to tertiary level geography students (8). Essentially most of the research reveals that geography educators require improved training and resources in order to improve the performance of school leavers who are examined on their ability to use aerial photographs, orthophoto maps and topographic maps, the latter being the basis of the matric geography practical examination introduced during the 1970's (9).

Task analysis, a basic CBT principle, was applied to this problem learning area in geography education at secondary schools in South Africa. The process revealed that a clear progression from basic map reading through map analysis to map interpretation of spatial information is required if learners are to become competent in the use of maps and other forms of spatial information. Figure 1 illustrates a skills hierarchy, based on the South African matric geography syllabus in use during the nineties when the research was initiated (1). Map interpretation was not clearly defined but was assumed to be based on the reading and analysis of spatial information.

TASK LEVEL 4
GRADIENT CALCULATION

⇩
depends on the capability of
⇩

TASK LEVEL 3
MEASURING DISTANCE; ASSESSING HEIGHT
(to be taught in either order)

⇩
which depend on the capability of
⇩

TASK LEVEL 2
LOCATING POSITION; DESCRIBING DIRECTION; MEASURING BEARING
(to be taught in any order)

⇩
which depend on the capability of
⇩

TASK LEVEL 1
READING CONVENTIONAL SIGNS (Map symbols)
THEIR IDENTIFICATION, RECOGNITION AND COMPREHENSION
(a starting point)

Figure 1. Task analysis, working backwards from the desired outcome.

Proceedings of the 21st International Cartographic Conference (ICC) — Durban, South Africa, 10 – 16 August 2003
'Cartographic Renaissance' — Hosted by The International Cartographic Association (ICA)
ISBN: 0-958-46093-0 — Produced by: Document Transformation Technologies

One way to address the problem of poor map use performance was to put self-instruction materials into the hands of both educators and learners that provide a clear, simple geographic concept framework for studying the people/place interface, appropriate topographic map extracts supported by lessons and illustrations that explain relevant terminology coupled with map reading exercises that can be marked by the learners. Because of the lack of computers in those schools most in need of upgrading map use performance, the programme had to be paper- rather than computer-based but still needed to be as efficient as possible. Drawing from research into reading theory (10, 11 & 12), geography teaching (13a & b, 14 and many others), map use teaching (13 c, 15a, b & c, 16, 17 to mention a few) and the principles of instructional design for CBT (18), a prototype self-instruction programme for learning to read the South African 1:50 000 topographic map was developed, trialed at a South African secondary school and evaluated (1, p78). Minor adaptations were made following the school trial and the LSM was later published as *MapTrix* (18).

The programme addresses only task level 1 in the skills hierarchy illustrated in Figure 1 - map reading. *MapTrix* consists of 52 work cards each with a different topographic map extract, one of twelve geography concept lessons, 10 photographically illustrated map symbol explanations and an exercise of 10 graded map reading questions (see Figure 2). The programme is structured like a pack of playing cards, the four suits representing four themes: landscape, transport, rural settlement and urban settlement. Odd numbered cards, even numbered cards and picture cards represent sub-themes (e.g. maps of mountains, valleys and plains appear on the work cards for landscape). The back of each playing card has the answers to an exercise on one of the work cards. An answer booklet guides each learner through the programme. A poster summarises the steps for introducing the programme that are suggested in the *MapTrix* Educator's Guide. The product is marketed as a Kit packed into a box (33 cm x 45 cm x 4.5 cm) that can be opened and folded up into a display stand for the work cards. A training video was produced by the NMO to assist educators with the implementation of *MapTrix* (20).

Figure 2. Selected components of the *MapTrix* Kit.

The Department of Land Affairs (DLA) marked the 80th anniversary of the NMO by sponsoring the publication of 3000 *MapTrix* Kits in October 2000 (21). The following year 2000 donated Kits were distributed to schools throughout South Africa. In 2002 these learner support materials were evaluated using a national questionnaire survey (22). The results indicated that the self-instruction methodology was very successful but while the use of the programme improved map reading ability amongst learners and improved the attitude of educators towards dealing with map use, the programme does not address the higher order skills of analysis and interpretation required for the matric geography practical examinations.

In the ongoing attempt to develop LSM that will improve the spatial competence of South African school leavers, the next phase in this research is to identify the nature and extent of the spatial analysis tasks in which those who have taken geography, should be competent and whether current teaching practice can meet their learning needs.

In this paper two questions are addressed:

- What spatial competencies do potential employers anticipate from school leavers who have studied geography to FET level?
- Are secondary school geography educators in South Africa equipped to develop these spatial skills?

2. INDUSTRY EXPECTATIONS REGARDING SPATIAL LITERACY COMPETENCE

A distinction is made between analysing spatial information and analysing the tasks performed using spatial information. Because the focus of this research is on the outcome of education and training in the use of spatial information, it is important to ascertain what competencies industry representatives expect from learners emerging from formal secondary education. So much has changed in the spatial information industry that guidelines from existing school textbooks on the topic of map use, need to be reassessed. Because the term spatial literacy is not widely used in geography education in South Africa an attempt was made develop a working definition of the term.

In September 2001 the author was invited to present a paper on *MapTrix* and MapAware to the Cape GIS User Group (CaGis) who, at the time, met regularly to discuss issues related to various GIS applications and the spatial information industry in general. A questionnaire survey was conducted with the 21 industry representatives who attended (Figure 3). This focus group of spatial information users was asked to help provide answers to a number of questions, especially - what is understood by the term spatial literacy? And with a view to guiding education and training in this area - what spatial information products are used most often, what tasks are regularly performed using spatial information, how difficult are these tasks and which tasks should school leavers be able to perform? To obtain these answers, a five-part questionnaire was used requiring participants to fill in a series of check boxes. They were encouraged to discuss their different sources of spatial information and the tasks they performed but each participant was asked to fill in their own questionnaire. Their responses were linked to their regularity of engagement with the products and/or tasks and although interviews were not conducted, queries were addressed by the author as they arose.

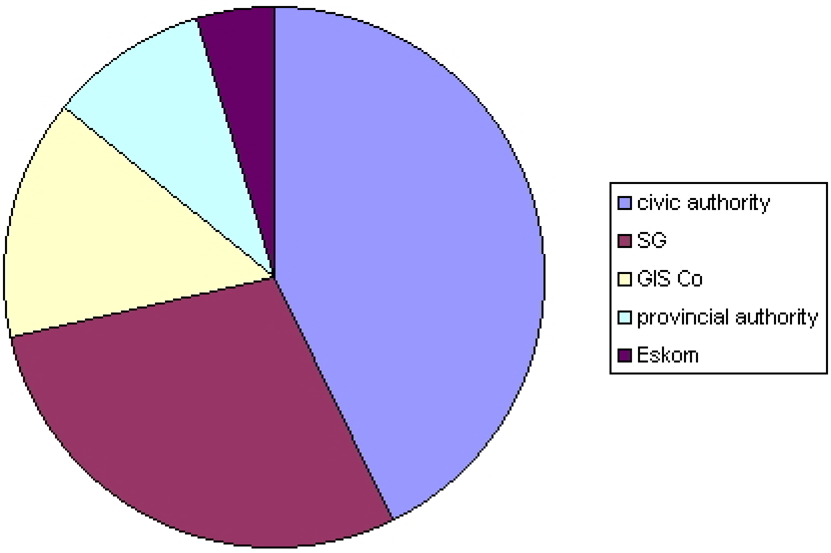

Figure 3. Employment sectors of focus group members.

In order to evaluate whether members of the focus group had specialised training in GIS applications they were asked to indicate the number of years of study beyond formal schooling they had received but without distinguishing between professional and technical training. The results show that only 15% of the sample had less than three years tertiary training, the balance had three or more years of training. As might be expected from staff with high levels of training, 48% were in supervisory or management positions, making them suitable candidates to consult regarding entry-level skills expectations. A breakdown of the employment sectors represented by the respondents shows that the majority of the users are employed in the public sector, responsible for the provision of services (Figure 3). Those serving in local civic authorities were the largest group, the second largest worked in the Surveyor-General's Office in Cape Town. One small group was employed by a private GIS company and the last two sectors by the Western Cape provincial administration and by Eskom, the electricity supply commission.

2.2 Defining spatial literacy

Participants were requested to review a proposed definition of spatial literacy (Figure 4) and approve, reject or amend it.

Spatial literacy is the ability to:

- read with understanding spatial information about the natural and constructed environment from various sources including maps and aerial photographs in paper and digital formats,
- analyse that information and present results mathematically and/or verbally,
- visualise the landscape from the interpretation of spatial information and
- present selected information graphically as required.

Figure 4. Proposed definition of spatial literacy.

None of the 21 participants rejected the statement, 19 approved it and two proposed amendments. One suggested that the list of sources should include satellite imagery and another that landscape visualisation should include proposed changes over time. Both would elevate the level of competence required to attain spatial literacy and indicate that perhaps a broader definition should be developed, one which differentiates between different levels of competence.

2.3 Spatial information products

A review of the spatial information products most commonly used in the GIS workplace was conducted (Figure 5). Structured responses were required to six spatial information products selected from those assumed to be in wide use. A partially open-ended response to thematic maps was requested and then participants were asked to indicate any other types and/or formats of spatial information that they use regularly. The products listed included the 1:50 000 topographic map (base map of the national mapping series, produced by the NMO), aerial photographs, 1:10 000 orthophoto maps (both available from the NMO and other sources), road maps, national or regional maps (various suppliers), and property diagrams which are available from the S.G. Offices. In order to establish guidelines for suitable learner support material, participants were asked to indicate how often they used each product and whether the spatial products they used most often are in the paper or digital format.

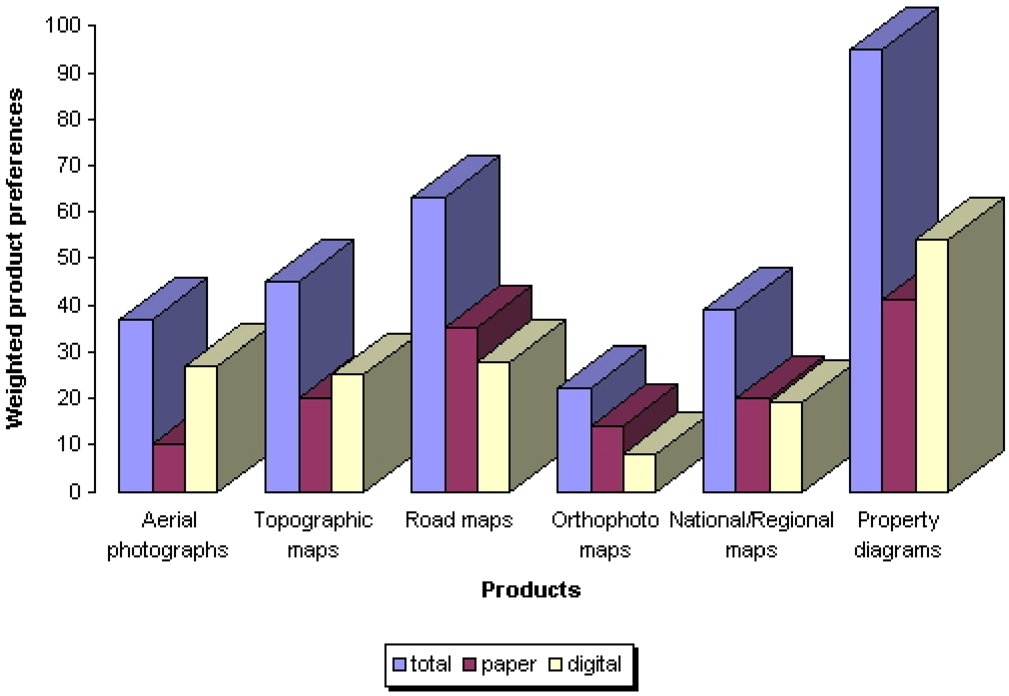

Figure 5. Spatial information product analysis.

Weighting of their responses was achieved by asking participants to indicate the types and formats of spatial information that they used on a regular basis. To quantify regular use, they were asked to distinguish between products used A very often (every day or alternate day), B quite often (once or twice a week) and C seldom (once or twice a month). For products used less than once a month they were asked to leave the check boxes empty. Very often was weighted 3, quite often weighted 2 and seldom weighted 1. These weighted scores for each product were compared so as to indicate those products that it would benefit learners to be familiar with, before leaving formal education.

Figure 5 represents the weighted breakdown per user of products in paper based and digital versions and reveals that property diagrams are used most often by the respondents. This might be expected when consulting the employment profile of the participants but stresses the importance of including such products in a learning programme. Property diagrams are not currently prescribed as learning materials. The spatial information products ranked second are road maps, again not prescribed learning materials. Topographic maps, prescribed material for the matric geography practical examination ranked third on the list of products used most regularly by the participants, followed by national/regional maps and aerial photographs. Orthophoto maps although prescribed material included in the matriculation examination, are used least often.

All products listed are available in paper and digital formats but use by respondents varied according to product type. Property diagrams and aerial photographs were clearly used more often in the digital format; there was also a slightly higher use of digital topographic data. Paper road maps and orthophoto maps were used more often than digital versions and there was an almost even balance of both formats used for national and regional maps. Overall it is clear that candidates at secondary education level should be prepared for the use of both paper and digital formats of spatial information.

Just over half the candidates (11/21) indicated that they used various thematic maps including urban land use zones, electricity consumption and various population indicators. The tasks they performed using these products were for comparative and/or interpretive purposes. These correspond with maps recommended for use in geography teaching, reinforcing their inclusion in learner support materials for map use. In most cases both paper and digital thematic maps were used with the same degree of regularity although three participants indicated that while they seldom used such maps, they used them only in the digital format.

2.4 Spatial information task analysis

In the light of experience gained while offering industry related training to adult map users at MapAware workshops, eleven specific tasks requiring the use of spatial information were identified. These are ranked and then differentiated into sub-tasks of successive levels of perceived difficulty (Table 1). Participants were again asked to fill the check boxes beside these sub-tasks with A, B or C depending on the regularity with which they performed them. Tasks 1 to 9 require some level of mathematical competence, 10 and 11 are considered higher level interpretive tasks and were included for the sake of the spatial literacy definition. They are eliminated from the lists of spatial analysis tasks that follow.

Table 1. Ranking of spatial analysis and interpretation tasks evaluated during GIS user group survey.

Task Code	Spatial analysis tasks divided into sub-tasks based on perceived difficulty levels
1a	Locating features using an alpha-numeric grid
1b	Locating features using latitude and longitude
1c	Locating features using survey co-ordinates
2a	Describing direction/bearing using 8 cardinal points
2b	Describing direction/bearing correct to approx. 2°
2c	Describing direction/bearing correct to 1° or less
3a	Calculating distance correct to approximately 10 m
3b	Calculating distance correct to approximately 1 m
3c	Calculating distance correct to < 1 m
4a	Describing location using an alpha-numeric grid
4b	Describing location using latitude and longitude
4c	Describing location using survey co-ordinates
5a	Estimating altitude correct to approximately 10 m
5b	Estimating altitude correct to approximately 1 m
5c	Estimating altitude correct to < 1 m
6a	Calculating/recording gradient as a ratio (height: distance)
6b	Calculating/recording gradient as an angle of slope
6c	Calculating/recording gradient as a trigonometric function

Table 1. continued

Task Code	Spatial analysis tasks divided into sub-tasks based on perceived difficulty levels
7a 7b 7c	Calculating area correct to 1 ha Calculating area correct to 10 m^2 Calculating area correct to 1 m^2 or less
8a 8b 8c	Identifying landforms by naming features Identifying landforms by describing slope form/aspect Identifying landforms by generating profiles
9a 9b 9c	Identifying regional/district boundaries Identifying boundaries of land use zones Identifying property boundaries
10a 10b	Visualising terrain, integrating natural and constructed landscape Visualising terrain, integrating natural and constructed landscape plus changes over time
11a 11b	Reproducing features by sketching/copying at the same scale Reproducing features by sketching/copying at larger or smaller scales

As with the product evaluation, participants were asked to indicate how regularly they performed each analytical sub-task, those performed very often were weighted 3, quite often 2 and seldom 1. The responses were totalled per task and the tasks were then ranked, in Table 2, based on the incidence of performance in the workplace. Participants were asked to list other tasks that they perform and only 5 added to the list. These tasks were digital data capture, digital terrain modelling, maintaining spatial information, creating thematic maps and defining statistics for specific geographic areas, the type of tasks that could be included in the envisaged instruction programme so that learners use maps for practical and relevant investigations (23) as opposed to 'doing mapwork'.

Table 2. Spatial analysis tasks ranked according to regularity of performance from most to least often.

Task number	Spatial analysis task	Incidence value	Ranking
9	Identifying boundaries	44	9
1	Locating features	33	8
3	Calculating distance	27	6
4	Describing location	27	7
7	Calculating area	22	5
2	Describing direction/bearing	15	3
8	Identifying landforms	15	4
5	Estimating altitude	11	2
6	Calculating/recording gradient	8	1

When comparing the tasks as ranked by the GIS users with those usually emphasised in South African geography textbooks, significant differences occur. Gradient calculation is often regarded as a high priority task expected of geography matriculants, however, the ranking in Table 2 shows that it is the task least often performed by the participants. Boundary identification is the task most often performed in the work place yet by contrast seldom appears in teaching texts or examinations. When identifying landforms participants were expected to name them rather than to profile them. This is in strong contrast to the stress placed on drawing cross-sections, a classic mapwork task in the classroom. The ranking of the spatial analysis tasks by this small group should be compared with ranking by a more representative sample of spatial information users including researchers and academics before deciding on the weighting that these tasks should be given in the proposed self-instruction programme for spatial analysis.

2.5 Task accuracy and perceived difficulty

While the review of the task frequency and accuracy expected by the participants provides some insight into the methods and materials that should be included in the proposed self-instruction programme; what proved to be much more illuminating was their opinion of the difficulty level of each task. They were asked to rank all sub-tasks in four classes from very easy, easy, moderately difficult to very difficult. Clear guidelines were offered for their classification including the school grade at which they felt these tasks should be mastered and a description of the spatial literacy competence of learners able to perform such tasks. Possible potential for employment, that mastery of the sub-tasks might entail, was also suggested. The data was collected by totalling the number of times each sub-task was placed in each class. The classes were then weighted: very easy (x 1), easy (x 2), moderate difficulty (x 3) and very difficult (x 4). The weighted scores were then totalled per task and ranked from the easiest to the most difficult task (Table 3).

Table 3. Spatial analysis tasks ranked by GIS users from easiest to most difficult.

Task number	Spatial analysis task	Difficulty score	Difficulty ranking
9	Identifying boundaries	94	1
3	Calculating distance	101	2
1	Locating features	110	3
4	Describing location	114	4
7	Calculating area	124	5
5	Estimating altitude	131	6
2	Describing direction/bearing	132	7
8	Identifying landforms	140	8
6	Calculating/recording gradient	156	9

2.6 Identifying an appropriate skills hierarchy for instruction in spatial analysis
Three factors can be taken into consideration when identifying the sequence and scope of the spatial analysis skills to be included in the proposed self-instruction programme – i tasks that are commonly performed, familiarity with which would be advantageous to school leavers, ii a skills hierarchy that could be followed in order to assist learners to develop the requisite mathematical concepts sequentially, gaining confidence at each level of complexity before progressing further and tackling more difficult tasks and iii preparation for the geographic interpretation of the spatial information about the landscape. While it may be assumed when comparing Tables 2 and 3 that tasks performed most often might be considered the easiest (e.g. identifying boundaries) and those less familiar (e.g. gradient calculation) more difficult, other trends emerge that suggest that tasks can be grouped according to difficulty levels independently of how often they are performed. Tasks 1, 3 and 4, often performed all fall between 2 and 4 on the difficulty ranking but not in the same order. Likewise tasks 2, 5 and 8 are seldom undertaken but appear in a similar difficulty ranking. However, because locating features (task 1) and describing location (task 4) require the same content knowledge it was decided to group them as one task requiring the same instruction text and illustration. Closer inspection of the difficulty ranking of the sub-tasks revealed that while describing direction was considered relatively easy, measuring bearing accurately (clearly a mathematical skill) was considered more difficult so it was decided to differentiate task 2 into two tasks (see Table 4). Although profiles are not often constructed in the workplace (according to this focus group), this task has been retained in the programme as a high level competence required for the geographic interpretation of landscape (such as distinguishing between slope forms or identifying microclimate zones).

Table 4. Hierarchy for spatial analysis skills for prototype self-instruction programme.

Difficulty level	Spatial analysis skills requiring mathematical competence
1	Identifying boundaries
1	Describing direction
2	Using or describing absolute location (using geographic co-ordinates)
2	Measuring bearing
3	Assessing altitude or height
3	Measuring distance and calculating area
4	Calculating gradients
4	Drawing or interpreting profiles (to identify landforms)

The findings of the GIS user group survey thus led to a significant re-evaluation of the skills hierarchy and scope that had been initially proposed (Figure 1) as well as the skills identified during adult training (Table 1). It had become clear that learners should be exposed to property diagrams and should also be able to describe the patterns associated with property boundaries (cadastral information) depicted on topographic maps. When evaluating the mathematical complexity of the spatial analysis tasks that had been identified, it was decided to change the ranking to represent the sequence of the mathematical tasks as well as their perceived difficulty level. Instead of 8 sequential tasks, tasks on the same difficulty level can be taught in any order but mastery of the lower skill levels must be attained before moving to the next highest skill level. Table 4 illustrates the skill ranking that was adopted as the framework for the development of spatial analysis exercises to broaden the scope of *MapTrix*. This hierarchy will be used in the prototype programme. Following trials to assess the efficacy of this programme, further adaptations may be required.

It is not assumed that this limited sample is representative of all employers in the spatial information industry nor all users of spatial information but their participation has thrown light on the path that educators should be preparing school leavers to follow.

3. GEOGRAPHY EDUCATORS ABILITY TO MEET SPATIAL LEARNING NEEDS

When evaluating *MapTrix*, educators confirmed that more advanced exercises were required to develop learners' ability to analyse and interpret spatial information (22). Included in the survey was an invitation to educators to collaborate in the development of such learner support materials. This produced very disappointing results, while 66 % of educators indicated (by ticking a YES box) that they would like to participate in the development of an advanced version of *MapTrix* only 3 of 92 educators who participated in the survey indicated their willingness to write exercise items by responding appropriately to the invitation. This could be interpreted as a lack of confidence in their own ability by the rest of the participants. Despite this setback, development of the programme was continued by differentiating map extracts in the *MapTrix* programme that would be suitable for integrated map interpretation exercises from those that could be used to teach the more mathematically orientated spatial analysis tasks (as identified in Table 4).

3.1 Collaboration of educators in LSM development

Collaboration was sought with practicing educators in the LSM development process because advantages include greater likelihood of adoption of the materials through ownership of the process and more realistically achievable learning outcomes (24). A valuable opportunity to involve educators in collaboration was presented during 8 workshops on *Developing spatial competency at global, continental, national and local scales* offered by the Western Cape Education Department (WCED) in collaboration with the NMO during February 2003. Included in the range of spatial information resources provided to these schools were *MapTrix* Kits, a world map learning game and a globe, also wall maps of the World, Africa, South Africa, Western Cape as well as ten each of each school's local 1:50 000 topographic and 1:10 000 orthophoto map sheets.

Three representatives each from 124 schools were invited to participate in the training workshops where the resources were handed over, however, only 192 geography educators attended the workshops. For one hour of the four hour workshop the group was divided into two. While 94 educators played Mapa, used the Smith GlobeMaps and assessed them and the accompanying Mini Atlas (25), 108 educators, responsible for preparing learners for the final (FETC) geography exam, participated in the collaborative writing of advanced map use exercises for *MapTrix*.

Thirty-six of the fifty-two map extracts used for *MapTrix* were regrouped to teach the spatial analysis tasks listed in Table 5 where the letters H, C, D and S stand for Hearts, Clubs, Diamonds and Spades, each grouped according to even and odd numbered playing cards. The guidelines for producing outcomes based learning opportunities, provided in the draft Curriculum 2005 documents (26), were adapted for 8 spatial analysis tasks and supplied to the educators. They were each asked to formulate 10 questions and answers that would provide learners with the opportunity to perform one of the analytical tasks. The need for clearly worded questions focussed on one possible answer was identified as being in line with outcomes based teaching strategies and imperative for self-instruction learning programmes where learners would later assess their own answers. The mathematical nature of such questions was stressed. The selected skills hierarchy was carefully described and explained before *MapTrix* work cards were distributed randomly to educators who were offered the option to exchange analysis tasks if they so chose. If each of the 108 educators had written 10 questions and answers, the result of this exercise would have been 30 questions per work card from which 10 could be selected. The results laid out in Table 5 tell a very different story.

The 108 educators who participated in formulating questions for the 36 map analysis exercises submitted 694 questions. After careful scrutiny 486 (or 70 %) were rejected. Only 137 or 20 % could be used as contributed. Rejected questions were later re-evaluated and in cases where they referred to the topic, practical map analysis or were relevant to the life experiences of adolescent map users, they were adapted. This led to a further 71 questions (10%) that will be included either by adding information to the question or reformulating the answers. A total of 208 questions can be used in the prototype self-instruction programme for spatial analysis. This represents 58 % of the 360 questions required. The rest of the questions were totally unsuitable for inclusion in the LSM. Of the 36 spatial analysis exercises requiring 10 questions each, only 7 (less than 20 %) are ready for the prototype learning programme. Collaboration in LSM development was once again found to be disappointing despite the fact that educators were offered remuneration for each question and answer that would be used in the programme should it be published.

Table 5. Questions formulated by educators per spatial analysis task.

Spatial Analysis Task	Work Card	Number of Educators	Questions				
			Submitted	Rejected	Adapted	Accepted	Contributed
Identifying boundaries and shapes	H3	4	32	24	6	2	8
	H5	2	8	6	2	0	2
	H7	2	12	8	2	2	4
	H9	1	4	2	1	1	2
Describing direction	C3	2	16	12	1	3	4
	C5	5	30	21	1	8	9
	C7	3	27	17	1	9	10
	C9	3	20	14	3	3	6
Identifying absolute location (co-ordinate position)	H2	4	29	20	3	6	9
	H4	2	11	6	3	2	5
	H6	3	19	18	0	1	1
	H8	3	20	11	0	9	9
	H10	4	23	20	0	3	3
Measuring bearing	C2	3	15	11	1	3	4
	C4	4	16	6	4	6	10
	C6	3	15	10	2	3	5
	C8	4	27	17	3	7	10
	C10	3	15	12	2	1	3
Estimating height	D3	4	25	22	3	0	3
	D5	4	25	17	5	3	8
	D7	2	17	11	2	4	6
	D9	3	18	17	1	0	1
Calculating distance and area	D2	3	18	12	2	4	6
	D4	3	19	9	3	7	10
	D6	4	23	20	0	3	3
	D8	3	17	8	4	5	9
	D10	2	8	3	2	3	5
Calculating gradient	S2	4	31	21	5	5	10
	S4	3	23	13	2	8	10
	S6	2	13	10	1	2	3
	S8	3	22	19	2	1	3
	S10	3	20	17	0	3	3
Constructing profiles	S3	2	16	15	0	1	1
	S5	3	25	15	1	9	10
	S7	3	23	14	0	9	9
	S9	2	12	8	3	1	4
Totals	36	108	694	486	71	137	208

3.2 Educator Training needs

It appeared that not all the educators involved in this exercise were aware of the distinction between reading, analysing and interpreting the spatial information on maps. Many appeared to find the task of setting questions very difficult with only 15 submitting 10 questions while 9 submitted only 2 or 3, the average being 6.4 questions submitted per educator. With the stress on the outcome of teaching (rather than on the content as was formerly the case) the formulation of appropriate exercises is vital if geography educators are to be able to assess whether learners can attain the map use competencies expected. If the incidence of question rejection can be linked to lack of educator competence, then the ranking of the spatial analysis tasks in Table 6 could suggest the areas where educator training is most necessary.

Table 6. Ranking of spatial analysis tasks according to lack of educator ability to write appropriate exercise items.

Spatial analysis skills requiring mathematical competence	Questions rejected per spatial analysis task
Estimating height	78.8 %
Calculating gradient	74.5 %
Identifying absolute location (co-ordinate position)	72.0 %
Constructing profiles	70.3 %
Describing direction	69.5 %
Identifying boundaries and shapes	66.7 %
Measuring bearing	64.1 %
Calculating distance and area	57.1 %

An analysis of the reasons for rejecting questions was undertaken to try and identify the shortcomings in educator preparedness for the task they had undertaken. From Figure 6 it is clear that the main reason for rejecting questions (22 %) was that they were so vague as to make the required analysis impossible or a correct answer unattainable. It was a matter of grave concern to find that 17 % of the contributions had to be rejected because the answers were wrong and that 12 % of questions referred to map information incorrectly. The questions rejected as too easy (15 %) were all map reading rather than analysis questions while 12 % were rejected because the questions were irrelevant to the topic. In 6 % of cases the answers were too long to be used for a self-instruction programme where accurate self-assessment relies on short unambiguous answers. Only a small percent of questions were rejected because they were higher up the analytical skills hierarchy (3 %) or beyond the scope of map analysis (4 %). Only (2 %) were rejected due to repetition.

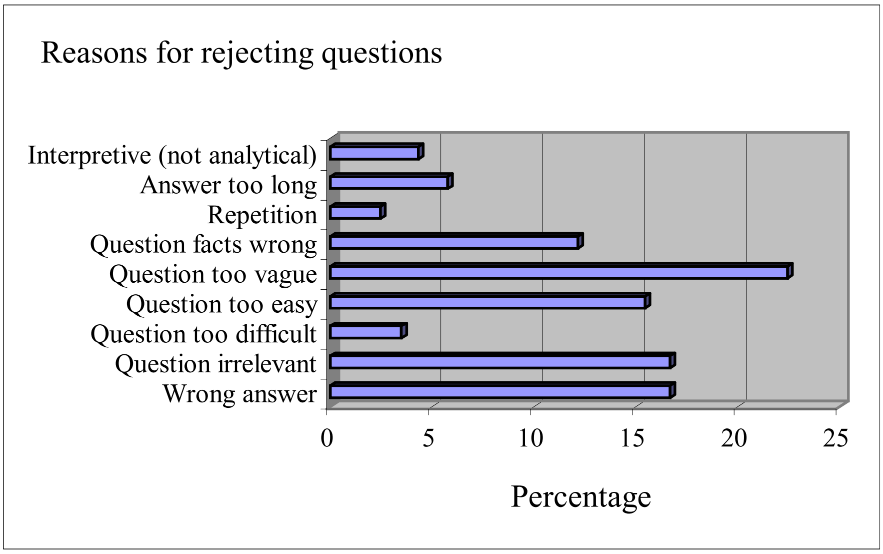

Figure 6. Analysis of rejected questions.

No biographical details were solicited from the 108 educators who participated in this study so as to preserve their anonymity. The only factor that identifies the group is that they were all responsible for teaching geography to FETC level at their respective schools and thus they may not be representative of all senior secondary geography educators in South Africa. They were from schools in 3 of the 8 management districts where the matric geography results for the previous year (2002) had been the lowest in the Western Cape Province. However, in comparison with the other 7 provinces in South Africa the WCED has a very high standard and is regarded as one of the education departments leading the way in educational reform. It must be stressed that the exercise of gathering questions for map analysis exercises was not undertaken in order to assess educator competence in this task but as a genuine attempt at collaboration in LSM development. However, the findings throw much light on the reasons for poor performance in the map use examination in geography education in South Africa. Further, the results suggest that educators' ability resulting from training is not adequate to meet the needs of the learners who, in turn, are unlikely to meet the expectations of prospective employers in the spatial information industry.

4. CONCLUSION

With regard to spatial competence there is a clear mismatch between what is expected in the work place and what is currently being taught at school level. As technology makes it possible to perform spatial analysis tasks more systematically and often with unprecedented levels of accuracy, so school leavers need to be taught differently. In the past copying maps by hand (often from an Atlas) and doing scale conversion exercises was considered good 'mapwork' but it does not teach modern learners of geography to ask and answer appropriate geographic questions as they investigate interrelationships at the people/place interface. If educators are to play their part in improving spatial competence they must be offered adequate training and resources. In relation to map use, teaching artistic skills as in the past must give way to developing mathematical skills in the present as we prepare school leavers to analyse and solve the spatial aspects of sustainability problems of the future. It is hoped that a self-instruction programme, using the existing *MapTrix* materials, to teach the maths required by map users will be useful in attaining this goal.

5. EXPLANATION OF TERMS AND ABBREVIATIONS USED

- CaGis: GIS user group based in the Western Cape Province of South Africa
- CBT: Computer based training
- CDSM: Chief Directorate of Surveys and Mapping, the national mapping organisation of South Africa
- Curriculum 2005: New unified education curriculum for South African learners, which is currently replacing the outdated, racially divisive education system of the previous government
- DLA: Department of Land Affairs in the national government (responsible for the NMO)
- FET or FETC: Further Education and Training Certificate offered after 12 years of schooling, which will shortly replace the matric certificate
- GET or GETC: General Education and Training Certificate offered after 9 years of schooling
- GIS: Geographic Information System
- LSM: Learner Support Material
- *MapTrix*: A self-instruction programme for learning to read the South African 1:50 000 topographic map
- MapAware: National map awareness and map literacy campaign of the NMO (1997-2002)
- Matric (abbreviation of matriculation): South African school leaving qualification currently offered after 12 years of schooling
- NMO: National Mapping Organisation
- S.G.: Surveyor(s)-General, responsible for cadastral information, the abbreviation is usually used with reference to their offices of which there are 4 in South Africa)
- WCED: Western Cape Education Department

6. ACKNOWLEDGEMENTS

The assistance of the CaGis members who participated in the user group survey is gratefully acknowledged. The contribution of the 108 senior secondary geography educators who participated in this study is greatly appreciated, as is the co-operation of the senior officials of the WCED who gave permission for this investigation. The questions that were contributed to the advanced version of *MapTrix* are greatly valued.

7. REFERENCES

[1] L. M. Innes, Learning to read the South African 1:50 000 topographic map: the development of a self-instruction method, unpublished M.Ed. dissertation submitted to the Faculty of Education, University of the Witwatersrand, Johannesburg (1998)

[2] L. M. Magi, Black university geography students' perception of school geography and the geography teacher, *South African Geographer*, 9(2), p145-153 (1981)

[3] M. StJ. W Burton, Graphicacy and the Third Dimension: an Investigation into the Problem of Poor Performance in Relief Mapwork in South African Schools, unpublished M.Ed. thesis, Rhodes University (1986)

[4] P. G. I. Sekete, An investigation into problems with topographic map comprehension by first year college of education students in North West (Province), Unpublished Master of Science research report, University of the Witwatersrand, Johannesburg (1995)

[5] T. Cowie, The relationship between standard 10 higher grade geography and the first year geography undergraduate course at university: an examination, *Geogram*, South African Geographical Society Schools Newsletter, 10, 3-7 (1994)

[6] E. C. Liebenberg, Teaching map use in a multicultural environment, *South African Geographical Journal*, 80(2), 111-117 (1998)

[7] T. Smit, The reading of topographical maps – an elementary model for secondary schools, paper presented at the IGU Conference Prague (1994)

[8] A. E. Tshibalo and S. Schulze, Co-operative learning in tertiary education: Teaching mapwork to Geography students, *South African Journal of Education*, 20(3), 230-234 (2000)
[9] D. H. Davies, School geography: a university perspective, South African Geographer, 15(1/2), 116-126 (1988)
[10] F. Smith, *Reading*, Cambridge University Press, Cambridge (1985)
[11] S. Silberstein, Let's take another look at reading: Twenty-five years of reading instruction, *English Teaching Forum*, October, 29-35 (1987)
[12] S. K. Kitao, *Reading, Schema Theory and Second Language Learners*, Eichosha Shinsha, Tokyo (1989)
[13] D. Boardman, *Graphicacy and Geography Teaching*, Croom Helm, London (1983)
[14] D. Boardman, *Handbook for Geography Teachers*, The Geographical Association, Sheffield (1986)
[15] D. Boardman, Learning with Ordnance Survey maps, in P. Bailey and P. Fox (eds), *Geography Teachers' Handbook*, Geographical Association, Sheffield, 117 – 123 (1996)
[16] R. M. Downs and L. S. Liben, The development of expertise in geography: A cognitive-developmental approach to geographic education, *Annals of the Association of American Geographers*, 81(2), 304-327 (1991)
[17] H. A. Sandford, Directed and free search of the school atlas map, *The Cartographic Journal*, 17(2), 83-92 (1980)
[18] H. A. Sandford, Objectives of school mapwork, *Teaching Geography*, October, 22-26 (1986)
[19] H. A. Sandford, School-based research into pupil's mapwork difficulties and their solution, in R. Gerber and J. Lidstone (eds.) *Developing Skills in Geographical Education*, International Geographical Union, Brisbane, 333-338 (1989)
[20] W. G. V. Balchin, Graphicacy comes of age, *Teaching Geography*, October, 8-9 (1985)
[21] R. R. Ballantyne, *Change in secondary school geography education: Teacher attitudes and practice*, Department of Environmental and Geographical Science, Report 60, University of Cape Town. (1987)
[22] R. M. Gagné and, L. J. Briggs, *Principles of Instructional Design*, Holt, Rinehart and Winston, New York (1974)
[23] L. M. Innes, *MapTrix: A Self-instruction Programme for Learning to Read the South African 1:50 000 Topographic Map*, Juta Education, Cape Town (2000)
[24] Chief Directorate: Surveys and Mapping, *Reading a Topographic Map with MapTrix* (video produced by Edumedia), Mowbray, South Africa (2000)
[25] P. Tickner, South Africa's National Mapping Organisation celebrates 80 years of service excellence, *International Cartographic Association Newsletter*, December, 2000 3-4 (2000)
[26] L. M. Innes, Evaluating learning material for map reading, paper presented at the International Geographical Union Conference, Durban (2002)
[27] C. F. Kohn, Real problem-solving in N. J. Graves (ed) *New Unesco Source Book for Geography Teaching*, Longman/The Unesco Press, 114-140 (1982)
[28] H. B. Lotz, H.B. The Development of Environmental Education Resource Materials for Junior Primary Education through Teacher Participation: The Case of the We Care Primary Project, unpublished D.Ed dissertation, University of Stellenbosch (1996)
[29] P. S. Anderson and L. M. Innes, Globe-maps: novelty or cartographic education necessity? Paper/poster to be presented at the International Cartographic Conference in Durban (2003)
[30] Department of Education, *Draft Geography Guidelines for Learning Programmes Grades 10 – 12 (schools)*, Pretoria, (2002)