



*working together to enhance understanding,
commitment and participation in engineering*

Engineering the Future

Newsletter 2

September 2007

EPSRC Engineering and Physical Sciences
Research Council



Introduction

As we come to the end of the first full year of the Engineering the Future Project we are circulating this second edition of our Newsletter. There is a lot to report. After a brief introductory note on our June seminar the Newsletter provides information about the on-going work in the schools/universities partnerships, in collaboration with industry and in partnership with the Scottish education policy makers. We finish with information from the perspectives of school pupils – who are perhaps our most important partners.

If there is anything in this Newsletter to which you would like to respond or comment or obtain further information on please contact:

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Update

Wednesday 12 September

On Wednesday 12 September school staff met with project staff to plan some of the practical arrangements for the new session. These included the trialling arrangements for school materials, (which school will trial which materials) and discussion on ways in which Curriculum for Excellence and the Project can support each other.

Seminar 11 June Ross Priory

Our first Seminar held at Ross Priory on 11 June marked a milestone in the life of the Project. The Seminar served a number of different purposes. It was a pleasure to recognise the work that had been done by colleagues in schools and universities in their collaborations on development work within schools; colleagues could see what others had done with a view to trialling next session. All associated with the Project contributed to reviewing the work that had been done throughout the year and to using this review to plan ahead for the next year. We had the opportunity to share with policy makers and possible ICT partners emerging themes or issues within the Project.

Some of the themes of the day are considered in more detail below and a full report of the Seminar has been prepared and is being circulated to all those who participated in it and to all those involved in the Project.

Feedback from those present was positive – helped by the location and the weather. Thanks are due to the staff of Ross Priory who ensured that the day was a comfortable and enjoyable experience for all participants. Particular thanks are due to Lynn Morrison and Sylvia Whitelock in the offices of the Department of Electronic and Electrical Engineering in the University of Strathclyde for all their advice, administrative support, attention to detail and good humour.

Partnership

A central principle of the Engineering the Future Project is that educational development requires genuine partnership and working with others. Our key partners include schools, universities, industry and policy makers in Scottish education.

Schools/universities partnerships

What has been achieved?

One of the most popular features of the Seminar was a poster session which allowed all to see the impressive range of work being done by the schools/universities partnerships.

Holy Cross High School (Brian Smith, Linda Glancy, John Burns)
Strathclyde University (Roy Chapman, Tony Gachagan, Tony Mulholland)
S5/S6

The **S5/6 Higher Physics Electricity and Electronics Unit** was the area selected for development. Our aim was to produce activities and material which met the following criteria: use of sustainable material, incorporation of up to date instrumentation, highlighting of electrical engineering in the 'real world', compatibility with the existing curriculum, and student orientated and hands on.

This year's project evolved in the following way. A visit by school staff to the EEE staff at Strathclyde University to identify areas of the Higher curriculum that would lead into engineering applications led them to focus on the Electricity and Electronics topic. A visit by school staff to Strathclyde to see the types of projects students are working on and the types of equipment they were using was useful in allowing us to purchase some similar equipment and to adopt some procedures for use by school students. Further to these visits we decided to identify activities and Outcome 3's from the Higher course that would meet our aims, particularly sustainability and relevance to the existing coursework.

The activities identified are:

- **the out of balance Wheatstone Bridge**
- **relationship between peak and r.m.s voltage**
- **relationship between frequency and current in a resistive circuit**
- **smoothing, op-amp saturation and calibration of a signal generator.**

We purchased a hand-held oscilloscope, a strain gauge connected to a Wheatstone bridge arrangement and a purpose made amplifier.

Students experience an active and practical approach to their learning.

- Students have the opportunity to use state of the art equipment helping to motivate this gadget generation.
- Students gain an insight into engineering principles that are applied to bring solutions to real situations.
- Students are given opportunities to improve their practical skills through participation, observation and recording.
- In the case of Outcome 3's students have the opportunity to write a report on their investigation which forms an assessable part of their mandatory course work.

We would like to extend this approach to the **Radiation and Mechanics** and the **Properties of Matter units** over the next two years.

Lanark Grammar School (Gerry Paterson, Aline Wilson)
Glasgow University (Catrina Bryce)
S5/S6

Here the focus has been on **S5/6 Advanced Higher Physics**. After taking into consideration the tight time constraints imposed on schools to complete this course, it was decided that what was to be developed had to be an integral component of the course but with an engineering slant to it. Since pupils at this level are required to complete a Practical Investigation as part of their assessment (20% of the marks of the course), it was logical to home in on this area as the content in the other units is far too crowded to even contemplate introducing any inserts. The project involves developing two separate **Practical Investigation units of work**. Pupils should be timetabled for 20 hours to complete this assignment but (as probably in many other schools) the pupils are required to use their own 'free time' to conduct the experiments and word-process the final report.

In any investigation at this level the candidates are usually required to measure some physical quantity using a number of different methods and then to compare/evaluate their final results. In the **Investigation on the Speed of Light**, c will be measured (i) using Foucault's method, (ii) using an electronic timing technique and (iii) by measuring ϵ_0 and μ_0 and inserting their values into Maxwell's equation $c = 1/\sqrt{\epsilon_0\mu_0}$. For the **Mobility of Charge Carriers Investigation**, 2 different methods will be employed using the characteristics of a n-channel Mosfet Transistor and then by examining the Hall Effect in an n-Ge semiconductor.

To introduce these experiments a Speed of Light Kit, Magnetic Probe and Hall Effect equipment were purchased. Hopefully the Agilent provided digital oscilloscope will be used for the electronic timing. The pupils will also visit Glasgow University Electrical Engineering Department to experience a more in-depth approach to the importance of these measurements in the world of telecommunications and semiconductor design.

The activities involved in these investigations at Advanced Higher level necessarily involve many of the (i) **characteristics of engineering** {understanding how things work, employing logic, effort, taking responsibility}; (ii) **engineering motivators** {human need to investigate, solve problems, using digital technology and exploring miniaturisation}; (iii) **learning principles** {employing different routes to solutions, problem solving and evaluating, checking results then rethinking the problem based on practical experience, observation and reflection.

Pupils are supplied with a detailed checklist indicating all the outcomes which need to be overtaken in order to meet the criteria for passing this unit. The development gives candidates the opportunity to work independently on an area of physics / engineering and allow them to make links with the University's Engineering Department which might well be the next port of call for some of them.

Dollar Academy (Deborah Keys, Pamela Webster)
Strathclyde University (Gordon Hayward, Ivan Andonovic, Walter Galbraith)
S3/S4 and S5/S6

At the moment we are approaching the project from three angles:

- **Developing a new ‘compressed course’**
- **Creation of a new post – Head of Applied Science and Engineering**
- **Electrical Engineering Higher.**

Most S3/S4 certificate courses in Dollar Academy are timetabled for 3 lessons per week. The school currently runs two ‘compressed courses’ that enable pupils to do 3 certificate courses in 6 lessons per week during S3/S4 rather than 9. Compressing Physics, Chemistry and Biology is a popular choice with potential Medics/Vets. Discussion with our Strathclyde University links highlighted the need for Engineering pupils to have business skills to maximise their chances of success when running their own business. This raised the possibility of a new compressed course: Physics, Economics and Technological Studies (PETS). We believe that we can streamline the teaching of Physics and Technological Studies with the possibility of freeing up teaching time to run additional activities and to organise trips and speakers.

It is hoped that more trips, visiting speakers etc will give the pupils a much better awareness of what Engineering is and can be and a clear understanding of the importance of Engineering and of the salaries/careers that can go with it. While they gain good passes at Intermediate 2 Physics, Economics and Technological Studies!

The PETS course was made available as an option for this year’s S2. 17 pupils of a cohort of 130 have opted for this combination. This is in addition to the 78 out of these 130 who have opted for Physics and the 5 out of 130 who have opted for Technological Studies as individual subjects.

Dollar Academy has created a new post with a new role - Head of Applied Science. The objective of this is to ensure the success of the PETS course and to explore and implement opportunities to develop applied science in the future.

Dollar Academy is also planning to run the AC circuit analysis Unit of the Higher Electrical Engineering Course for S6 students who are planning on taking Engineering degrees. Hopefully, this will mean that they will be better prepared once they get to University.

*Belmont Academy (Douglas McNeil, John McLellan, Ross McMahon)
Glasgow University (Tim Drysdale)
S3/S4*

The school has been exploring building engineering links into the **S3/4 Telecommunications and Electronics units**. Given the central role of electronics in modern engineering the main focus has been on this topic. A Project on LEDs and photodiodes has been introduced into this unit which has afforded S3/S4 pupils opportunities to use a wide range of equipment including signal generators, CROs, LEDs, coloured filters, fibre optic cable and a parabolic reflector.

This project is carried out in class time during the Electronics unit.

Experiment 1 posed pupils with the problem of how they could send a signal from an LED to a photodiode. Pupils worked in groups of two. Their task was to obtain an output trace from the Photodiode on the CRO, then with a stable signal on the CRO, to investigate the following.

1. The effect on the output when they change the output voltage from the signal generator
2. The effect on the output when they change the frequency from the signal generator.
3. The effect on the output when they change the shape of the signal (Sine, Square, Triangle) from the signal generator.
4. The effect on the output when they place a red, green or blue filter between the LED and the Photodiode.
5. The effect on the output when they use other LEDs, trying different coloured and two coloured (Red-Green) LEDs.

The experiment was originally planned using a Double beam CRO to compare the input and output signal but experience showed that this was difficult for S3/S4 pupils to set up.

Extension problem solving experiments can be demonstrated by the teacher or done in rotation by pupils. These included finding means of sending a signal from a LED sent longer distances to a Photodiode. Possible solutions include the use of fibre optic cable and the use of a parabolic reflector.

This work reinforces concepts taught in class and allows pupils to work with modern equipment to test concepts in new situations.

Two other investigations are being developed. A **Solar Cell Investigation** fits well into the 'Energy' topic and emphasises the importance of renewables. Carried out as an investigation for **Practical Abilities**, this work investigates how the voltage of a solar cell varies with its angle to the sun in the horizontal and vertical planes. Pupils must solve a practical problem and optimise a solution. This problem relates to real life as we need to develop renewables due to increased world demand power and the threat of global warming. An **Electromagnet Investigation**, the paper clip challenge, uses physics and engineering principles to teach S3/S4 pupils about both financial and environmental costs. Pupils select electromagnets with 50, 100, or 200 turns and a number of 1.5V batteries. Pupils build a simple circuit using these

components and others (including a Joulemeter). After hypothesising which combination would be most efficient (i.e. use the least energy to lift 100 paperclips from one box to another.), pupils experiment and test the possibilities to find the most efficient combination of magnet and power supply to complete the task. They make use of $E = P \times t$, $V = I \times R$, costing, environmental cost, efficiency and sustainability. Projects can be done individually, but are best suited to small groups. This project encompasses all four capacities of a Curriculum for Excellence.

Balforn High School (Roy Pearson, Phil Slavin)
Strathclyde University (Gareth Pierce, Craig Michie, Martin Judd)
S1/S2

Five possible projects were discussed and a decision was made to develop projects on **Bat Detector & Ultrasonic Propagation** and on **Energy Management** for **S1/S2** pupils.

The Bat Detector Project is built on clear principles:

- Pupils must gain an insight into the problem solving nature of electrical engineering.
- Work must have a practical basis.
- The content must be appropriate for age and stage, but must take pupils beyond what is normally possible in class.
- Teaching will incorporate cooperative learning techniques.

Each pupil builds a device to monitor sounds inaudible to humans. A number of background skill areas are addressed:

- Hardware construction
 - practical electronic engineering
- Use device to investigate nature of ultrasound
 - basic physics of propagation
- Use device to survey local bat population
 - Interaction with biology aspects
- Working in groups
- Taking unit home for evening bat survey

The Bat Monitoring project requires special equipment for the assembly aspect (soldering iron, multimeter, basic tools) and may require additional equipment for the ultrasonic propagation experiments. The school has good links with the RSPB, who will be asked to put up bat boxes which will be monitored over time.

On completion of the activity pupils will: know that bats communicate using ultrasound, know that ultrasound can be detected using a transducer, be able to operate a bat detector that produces an audible sound, be able to use the detector to investigate bat behaviour and distribution in their local area, and have an understanding of how electrical engineering can be used to solve a problem. It is estimated the project will take four periods.

The **Energy Management Project** is related to the installation of wind turbines at Balforn. University of Strathclyde could provide wireless telemetry to record wind

speed and direction measurements which pupils can relate to energy generation and usage; this can be further integrated with a wireless system to measure energy usage through school through direct electrical, lighting and temperature measurements.

The Project may not integrate readily into the 5-14 curriculum but it matches readily with proposed science outcomes in a Curriculum for Excellence as it affords broader connections with engineering in general through discussion of energy generation, renewables etc, the uses of wireless communication technology and mobile communications and through utilising applications within a mobile environment.

St Aloysius College (James Cluckie)
Strathclyde University (Stephen McArthur, Phil McGlone)
Glasgow University (Phil Dobson)
S1/S2

An **Electronics Module** based on the **Mars Rover** has been developed for **S2** pupils which could also be used with Intermediate 1 or Standard Grade pupils in S3/4. The outcomes tie in with:

5-14	Level D	Earth In Space– Methods of Space Exploration
	Level F	Properties and Uses of Energy– Electronic Systems
Int1	Unit 6	Electronics
SG	Unit 4	Electronics Sections 1-4

This topic was picked for various reasons. Firstly it was felt that the existing module previously used in the school was failing to motivate and engage too many pupils. Secondly it was thought that this particular topic would lend itself easily to an engineering approach since it is easily modularised and can be done in teams. Lastly by tying it in with the Mars Rover it would be seen to be up to date and would also help motivate pupils.

The project will take about 4 hours to run and will run in this form with our S2 class next April/May. It is based on the MFA (Microelectronics for All) boards which are already used in many schools in Scotland. It could be adapted fairly easily for other logic systems. The extension materials use free web resources but could also dovetail into the Lego Mindstorms system..

Key principles have been embedded in the project. It is characteristic of engineering in that it is solution-oriented, adopts a systems approach, makes use simulation and requires team work. The problem is based on a real situation and mirrors the reality of professional engineering. Space exploration is attractive and motivating to most young people. Motivation is further enhanced in that the learning is driven by a particular need and pupils are given specific responsibilities. The purpose of the learning is made clear at all stages to pupils. The learning is experiential, the pupils have responsibility and the principles of teamwork are addressed explicitly. Many learning styles are provided for and the very open ended nature of the project supports adaptation and extension.

Williamwood High School (Lyn Robinson, John Brown, John Honeyman)

Strathclyde University (Campbell Booth, Brian Stimpson)
S1/S2

The project is designed around an **Energy/ Electricity topic** for **S1** pupils to fill a gap in current provision. Because at present there is no teaching of microelectronics at this stage a project in this area would be helpful. The basic scenario is to build a security system for a room incorporating several different methods of detection and different alarm systems. This builds on pupil interest in crime prevention and detection (CSI) and introduces them to some aspects of modern technology.

Pupils will learn first hand in a practical way how to solve problems relating to home security. They will learn about basic input-process output systems and the use of certain electronic components as the basis for many different systems.

The project will fit within our current Energy/ Electricity topic in first year and should occupy 6 periods. It uses alpha boards and although a few more specialised boards may need to be purchased the school has most of the other boards available. Some specific items are required such as a laser pointer but these are inexpensive. Initially the work will be undertaken by the physics staff, with their own classes, and any problems identified and hopefully solved. This should take place in November 2007. Staff development would be required for chemistry and biology staff, which will be assessed while the physics staff are teaching the topic to their own classes.

Pupils will work on different aspects of the project in groups of four or five and then present their work to the rest for the class for discussion. A simple answer will be achievable by all groups, but far more complex ones could be developed by some groups. This investigative style encourages creativity, allows for peer assessment and development of presentation skills, relating to key areas of Curriculum for Excellence and Assessment is for Learning.

New school partnerships

The Project welcomed three new schools as partners. One is in East Renfrewshire (Williamwood High School) and two are in Dumfries and Galloway (Dumfries Academy and St Joseph's College). Williamwood's proposed activities have been described above. In St Joseph's College the initial focus will be on S2 with perhaps some development in S1. The partnership will seek to develop curricular elements based on activities within the school's existing Engineering Club: a key principle is to have pupils develop their own ideas for projects which would be undertaken by other pupils. The focus in Dumfries Academy will be on engineering in the S1 broad-based science course. There is potential for building practical engineering projects into an expansion of the Energy section of the S1 course. The course book used includes work related to renewable energy sources (wind turbines, bio-fuels, solar power, fuel cells). There is the possibility of follow on in the second year of the S Grade Physics course where the Transport Unit could be rewritten to include engineering.

Careers Education

From the information provided in schools we have developed a careers education package for school staff and pupils which provides information on engineering as a graduate career which we hope is both accurate and attractive.

University Developments

As the Project moves into its second year then partnerships will be focusing on development work within the two University Departments as well as that within schools. To support our thinking in this area the 11 June seminar enjoyed an input from Professor Noel Entwistle on teaching and learning in University electronic engineering. In so doing Noel drew on some of the key messages which had emerged from the ETL project which had been based around Edinburgh, Durham and Coventry Universities.

The main concepts used in the ETL project were:

- Ways of thinking and practising in the subject
- Teaching-learning environment provided
- Constructive alignment of teaching with aims
- Students' approaches to learning & studying
- Students' experiences and perceptions of the teaching-learning environment

A key message regarding the constructive alignment of teaching with its espoused aims is summarised by John Biggs: 'A good teaching system aligns teaching method and assessment to the learning activities stated in the objectives, so that all aspects of this system act in accord to support appropriate learning. This system is called constructive alignment, based as it is on the twin principles of constructivism in learning and alignment in teaching.'

Students had demonstrated three main approaches to learning and studying:

- Deep approach in which they sought personal understanding by questioning, relating ideas and looking for patterns
- Surface approach – in which they reproduced lecturer's material by following routine procedures and memorising
- Strategic approach –where the student intended to get high grades through developing knowledge of assessment procedures, organised studying, time-management, effort and concentration

This presentation stimulated discussion on the implications for teaching in EEE including such matters as the concept of 'threshold concepts', the demands for content coverage, the balance between knowledge and skills, and the importance (and possible difficulties) of encouraging deep learning.

The coming session will afford opportunities for university and school colleagues to work cooperatively on developing practice in promotion continuity and progression from school to university EEE courses.

Partnerships with Industry

Agilent

Agilent Technologies is a major US company based in Santa Clara, California; Agilent Labs, their central research organization, has a branch site in South Queensferry. The Project has enjoyed the advice and support of Agilent since its inception last September. The company's commitment was demonstrated by their making available to each school in the Project a digital oscilloscope, supported by the necessary software. The oscilloscopes have been provided and are now available to schools. The company is also providing the supporting software and is making arrangements for staff development in its use. We have also been fortunate enough to be able to draw on the advice of Agilent with regard to our publicity. Agilent have also agreed to provide funding to the project to take forward the development of e-learning materials both for pupils and for staff.

E-learning

Time on 11 June was devoted to e-learning and, more specifically, to the potential of games as a learning tool. One of the planned outcomes of the Project is the development of exciting, easily accessible material. We are developing our understanding of the potential of e-learning with TPLD, a Dundee-based company with wide experience of the use of games as an effective means of promoting learning,

Helen Routledge of TPLD, led discussion on this at the seminar. The session focused on TPLD's analysis of the potential of games-based learning. Helen suggested that a paradigm-shift has occurred:

- e-learning has become more significant than print as a means of learning and under-35s are 'digital natives'
- Effective e-learning is not automatically facilitated just by the existence of the technology: e-learning also exploits the potential of experiential learning; its key characteristics are that it is learner-centred, involves 'learning by doing' and is very engaging.
- Games are 'powerful learning tools' which can improve learning, literacy, communication, teamwork
- All the learning and teaching aims set out in the Project's principles papers can be promoted by e-learning.

Helen made clear the difference between simulations and games in that simulations usually involve right/wrong decisions and/or representations of 'real life' made manageable for a learning/teaching situation while the key features of games are to motivate engagement through their fun element and to support multiple solutions to problems. Indeed, there is a lot of physics in many commercial games which schools could exploit

During the discussion that followed differing views of the potential of games based learning emerged. Some participants thought that there was real potential in this

approach; others were concerned about the links between games and learning and about the current state of technology in schools and its ability to cope with this approach to learning. This is an area that needs to be investigated further.....

Seminar participants felt that if games were to have potential then any games must be integrated in the curriculum and are likely to take account of cross-curricular issues important in engineering, such as marketing and economic growth. Experience elsewhere has shown that if we want to develop the potential of games-based learning fully, we should be seeking the collaboration of 'digital natives' – young people themselves.

We intend to take forward this session our thinking on the contributions games based learning can make to pupils' learning related to engineering.

And finally

RS Components is a major supplier of electronic hardware to UK universities and schools. Discussions are underway between RS and some project schools about the supply of equipment and components.

Partnerships with Scottish Education

A Curriculum for Excellence

Science has been a major focus in recent the development work of a *Curriculum for Excellence* and in the engagement of the profession with this.

Outcomes have now been written for each of the major science areas. These are written so as to ensure experiential learning and support personalisation and choice and depth of study. The potential for each outcome to support the development of a range of skills and to make evident their contribution to building the four capacities is crucial.

Planet Earth outcomes were published through a series of regional seminars and have been available for general engagement since the early summer.

The remaining science outcomes are yet to be published. Staff from the Engineering the Future Project have been in discussion with those developing the science curriculum. We believe that the final documentation will give clear indications of the potential for engineering activities within primary and early secondary science. It is already evident that the topics being developed by the schools in the Project relate immediately to draft outcomes while, more generally, the principles which colleagues have used to underpin their planning relate clearly to the four capacities. We hope to

support those working within the Project in playing an active part in engagement over the statements of outcomes as they appear.

Engineering the Future staff are continuing in dialogue with colleagues in Learning and Teaching Scotland on the ways in which the interface between science and technology can be creatively developed.

Contact <http://www.acurriculumforexcellencescotland.gov.uk>

What do pupils think about Engineering?

We have to thank the colleagues in schools who have returned to us 869 completed questionnaires; we are grateful also to Hannah Owen who was employed to input data into SPSS a program which supports analysis. But of course the people who deserve the biggest thanks are the young people who gave time, care and attention to completing these questionnaires.

Some initial findings follow (percentages rounded to the nearest unit):

- Of the 869 school pupils who had completed questionnaires (in all years from S3 to S6) 45% were female and 55% were male; this contrasts with the 177 first year university students of whom 5% were female and 95% were male
- Of the school pupils who had completed questionnaires 96% had received advice on subject choices from some source; the important role of guidance colleagues (and other senior staff) in school is evident; even more obvious is the key role of family and/or friends:
 - careers advisors (17%)
 - senior/guidance staff (54%)
 - other teachers (3%),
 - other sources [e.g. internet] (25%)
 - family/friends (86%)
- 65% of these school pupils had never considered engineering as a career choice - of the 289 respondents who had considered this career option, 78% were male
- Over 50% did not note any encouragement to study engineering or take this up as a career with 56 (7%) suggesting they had been discouraged by teaching staff but
 - 10% noted the encouragement of careers advisors
 - 30% said teachers had encouraged them
 - 32% noted the encouragement of family and/or friends
- 85% had not participated in any out-of-school activities related to physics or technological studies
- of the 800 studying Physics at any level:

- 378 (43%) respondents had been influenced by affective reasons, including a positive attitude to the subject or teacher and friends choosing physics
- 455 (52%) selecting physics had been influenced by reasons related to instrumentality (good for career, necessary for university) and/or their capacity in the subject
- 139 (16%) respondents noted that they had been 'put off' taking physics

When asked about their views on what they find enjoyable about mathematics teaching in school approximately 2 out of 3 pupils find their mathematics classes enjoyable because of what they are learning – a cheering thought! Regrettably, more than one in ten pupils found nothing (or very little) enjoyable.

When the question was posed as to what they found difficult, in mathematics a substantial minority found none of the subject difficult while those who did find the subject difficult nearly always referred to aspects of the content rather than to structure of the course or the way in which it was taught.

Only a small minority of pupils found nothing (or very little) enjoyable about physics teaching in school. Most pupils considered that their enjoyment of physics was related to subject factors rather than contextual or affective factors. A cheering thought: approximately 4 out of 5 pupils like the physics aspects of their physics classes.

When the question was posed as to what they found difficult, one in ten pupils found none of physics difficult while those who did find the subject difficult nearly always referred to aspects of the content rather than to the organisation of the course as the source of difficulty.

We will be examining these results in more detail but they already provide considerable food for thought.

Website

The Engineering the Future website is soon to go live at

www.engineeringthefuture.info

This provides links to the various development aspects of the Project and to related sites of interest. You will see from this Newsletter that we have adopted a new style of presentation which we intend to be a brand for all our public sites.