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Enhancing undergraduate student skills to meet research challenges: Case Studies and Examples

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Abstract:

The objective of embedding research activities in the undergraduate teaching programs at State Engineering colleges in India is worth pursuing and is certainly beneficial to all stakeholders: local industries, students and lecturers.

One of the main objectives of incorporating research at an undergraduate level is to enhance student's lateral thinking skills. We want them to develop the ability of analysing an engineering problem from first principles and recognise as well as take into account the work done by others in the field. In the knowledge driven society that is becoming truly global and interlinked, we need to equip students with an ability to challenge the status quo with independent and logical thinking. The expectation would be that students would provide solutions that offer better returns on investment for their employers. This is likely to enhance the culture of innovation in industry and increase profitability of the business.

In this article, I would like to share some examples and cases studies of how research can be embedded in the teaching based on my personal experience at Swansea University.

My examples would range from activities that we undertake for the benefit of Swansea University undergraduate students including Government assisted programs to link student, academia and industry.

Introduction:

Embedding research in teaching at State Engineering colleges in India is highly unlikely to succeed if it is done in isolation. It requires cultural change and relentless pursuit towards the objectives identified in the abstract of this article in everything we do. It is best achieved incrementally with small goals, taking small steps that bring immediate benefits to students and local industry.

In this article, the perception of research and research categories are defined first. The second section describes a UK vision for research. It will try to develop a context in which we are working and help us to provide relevance for our decisions and actions. Examples of embedding research at undergraduate engineering courses are described in the following section. The last section will extend the discussion thread at the post graduate level and give further examples of how students, academia and industry can work together for mutual benefits. An example of a multimillion pound ASTUTE project that pools the academic expertise across Wales for the benefit of Welsh industries is described as an appendix to this article.

How do we interpret Research for engineering colleges?

The perception of' research and innovation' is entirely different for different communities e.g. SME's, large national companies, large multinational companies, research led Universities and higher education institutions. It is important to understand these differences so that expectations from stakeholders – students, industrial partners and funding bodies can be managed and collaborations achieve a desired level of success.

For a new technology, the technology readiness level is normally defined on a scale between zero to ten. Technology readiness level of zero means absolute fundamental research stage and commercial application may or may not develop. On the other extreme, the readiness level of ten means prototypes are proven, beta versions tested and the technology is ready to enter the mass market. Universities tend to undertake research on problems with technology readiness level between zero and a maximum of six or seven.

I would classify research and the technology readiness levels into four categories:

1. **'No one else knows – only I know' category**: In this category the researcher is expected to undertake fundamental or basic research. Normally the researcher is based in a research led University. This is a high risk 'blue sky' research. This means the benefit to industry may be seen in five to ten years. This research is expected to result in developing a disruptive technology that can change industry standard and hence it is mostly funded by research councils or 'tax payers'. The technology readiness level for this research is between zero and two.
2. **'Very few people know it and I can advance the knowledge' category**: This is beginning of collaborative research among different groups in the world who incrementally enhance knowledge boundaries. The researcher is able to understand papers published by other authors and contribute to the knowledge by publishing his/her own experience. PhD and post doctoral students actively participate in this category. Again mostly undertaken in Research led Universities. The technology readiness level is slightly higher say between 1 and 4.
3. **'Many people know it but each one knows part of the solution' category:** This is the spirit of industrial collaborative research. Most aspects of the knowledge are established in the academic community at a technology readiness level ranging from three to six. The researcher is expected to understand the literature in this field and translate in the format that is required by his/her collaborating partners. Together, they bring in interdisciplinary expertise and provide a better solution with a technology readiness level up to seven. The benefits can be transferred to industry partners to develop a collaborative customised solution. Many times work undertaken in this category leads to work that may fall in the second category just described.
4. '**Most people know it and my role is to provide a knowledge bridge' category:** In this category the researcher is expected to translate the existing research knowledge in a language that a collaborating partner would understand and benefit from it. The expertise of the researcher in this category would help the collaborating partner to understand the 'state of the art' easily and efficiently. The collaborating partner should be able to relate this additional knowledge to business benefits. This is where most State Engineering colleges or

> Higher Education Institutions in India can develop their space and support local SME's as well as large national companies. Undergraduate students can learn and discover solutions within academic environment and develop necessary practical skills to solve industrial problem. It is a low risk and low cost option for SME's to collaborate with engineering colleges and bring immediate benefits within their industry.

In my opinion, one of the challenges that Indian state engineering colleges would face in the process of engaging in research is identifying a 'role' or 'space' that would give them an edge over IIT's. IIT's are funded differently and have an existing research culture. However, every state has at the most one IIT in comparison to a much larger number of engineering colleges that spread across the state. The geographical advantage that state engineering colleges have in India must not be overlooked. If the state engineering colleges start research in category four and transfer the relevant skills to their students and then it is very likely that SME's would choose/prefer local engineering colleges over IIT's on a number mini research projects. I will give some examples of such projects later in my article.

A Vision for UK Research:

One of the greatest advantages of UK system is that its agile, it adapts, it reflects and it grows. In the Education sector also its aims to punch above its weight. It is currently only second to United States. A recent study (published March 2010) undertaken by the Council for Science and Technology (http://www.bis.gov.uk/assets/bispartners/cst/docs/files/whats-new/10-584-vision-uk-research.pdf, last accessed 21st July 2011) gives a context to the need for engaging into research in all four categories described above. Some of the quotes from the document would help me to illustrate my point and it may encourage the reader to read the document that is freely available on the internet.

"We must have an education system which prepares everyone for living in a world where science and research are deeply embedded in our culture"

"The researchers' life cycle beings at school. Those school students who express interest in science subjects should be encouraged to carry out research projects either within their schools or even through vocation placements in a research laboratory."

"The emphasis of undergraduate teaching should be on the excitement of research and its ability to bring about a better understanding of ourselves and of the world around us. The focus should **not** be on accumulating factual knowledge, which will increasingly be better supplied by digital resources, but rather on the great ideas and how they were developed."

"We must have thriving universities and research communities, enriched by working with and across different sectors, delivering highly-skilled, entrepreneurial people to the labour market"

"Government should strengthen the pipeline into science in schools through good teaching, communicating the excitement and importance of science, and by exposure to hand-on research."

"The competition from India and China is more in engineering than science. India has the human capital, the necessary funding and the policy agenda necessary to establish this position."

"On 1st April 2005, 391,000 personnel were employed in R&D establishments in India, of which 40% were directly engaged in research. In 2006-2007, the Higher Education Sector consisted of 11 institutes of national importance, 358 universities and 20,677 colleges. These taught in excess of 11 million students"

"India's current five year planning cycle aims to achieve:

- an education system which nurtures creativity
- an R&D culture and value system which supports both basic and applied research and technology development
- an industry culture which is keen to interact with academia
- a bureaucracy which is supportive
- a policy framework which encourages young people to enter into scientific careers
- an ability to scan scientific developments in the world and use technology foresight to select critical technologies in a national perspective.

Clearly, Indian State Engineering colleges have great potential. They have student numbers and easy reach to local industries. Their student strength is much larger than IIT's and even with simple initiative and by taking small steps they can create their own space in this market and compete with IIT's in the space defined and controlled by them.

Examples of embedding research into undergraduate teaching:

The objective is to get students into a habit of independent study by accessing and assimilating information with their own initiative. As pointed out in the previous section, the emphasis of undergraduate teaching should be on the excitement of research rather than accumulating factual knowledge. It does however help if students are guided towards resources available on the internet. A significant proportion of these resources is freely available on the internet or in some instances can be obtained by contacting authors.

The easiest way to introduce these resources is through the modules that we teach. Some of the video recordings are available on YouTube others can be accessed via Google search. Other examples of websites that have a large collection of video lectures are http://videolectures.net/ ; http://ocw.mit.edu/index.htm (MIT free online courses) and http://freevideolectures.com/

Although this can be achieved through all engineering modules that are taught at the undergraduate level, some specific modules can be developed to enhance these skills

1. During the first year of study at Swansea University, almost all of our Engineering students undertake a 10 credit "Engineering Skills" module in first semester. The course aims to develop student's written and oral communication skills in the context of multi-disciplinary engineering project. For Swansea, the multidisciplinary project is the BLOODHOUND project (a car that would extend the land speed record to 1,000 mph using a jet and rocket powered engines). It was an easy choice for us as we are leading the computational effort on this project. However, other examples of multi-disciplinary project could range of any large scale engineering projects covering structural, automotive, marine, electrical/electronic or

aerospace projects. It can highlight the achievements of a successful project or explain a why a particular large scale engineering project failed and what are the lessons learnt.

Students are split into small groups and presentations, feedback and discussions may occur throughout the first term with each group assigned to a specific academic staff. This opportunity can be further utilised to enhance student's time and project management skills, programming and ICT skills, alongside the Career planning and professional development skills with appropriate lectures. Key employers can be invited to speak on their current challenges and projects and address their expectations from fresh graduates. These lectures can be live or video recordings for the exclusive use of State Engineering colleges in India.

2. The College of Engineering at Swansea University also offers a 10 credit "Research Dissertation" module to its fourth year engineering students. This module is in addition to group design projects and final year engineering projects that engineering students must do in almost all engineering colleges. The objective of this module is to enhance student's literature review skills. This is a core skill and a first step required for any research based degree whether it's MRes or PhD – whether the research is done in the University or in a multi-national company. The students first find the most relevant 50-70 recent journal papers by searching through a web portal such as 'Web of Knowledge' (http://wok.mimas.ac.uk/) and Google search. Web of Knowledge portal requires subscription however, using key word search it is possible to review large collection of academic papers across various journals/conferences published on a specific topic. The search can be expanded via authors or cited publications. Students can learn to use these skills in number of ways during their undergraduate degree. The committed students may also search various national and international funding council's websites where they normally publish the abstracts of successful research grants.

   The students review these materials and form an individual, well rounded report supported by evidence on the state of the art. They compare and contrast, discuss pro's and con's, advantages and limitations of various methods, techniques and application areas. The successful students may discover research gaps and suggest a way forward. There are number of examples where students discovered their research aptitude while undertaking this module and decided to pursue research at the PhD level to further enhance their knowledge.

   Sample recent examples of research dissertation projects are listed below.

   I. Turbulent flow modelling and its applications in Aerospace Engineering
   II. High performance materials in Aerospace
   III. Metallic Glasses
   IV. Reliability of tidal turbines
   V. Predicting the strength of the laser for prostate cancer treatment
   VI. Printable chemical sensors
   VII. Additive manufacturing
   VIII. Trends in Condition Monitoring

IX. Green Car
X. Numerical computation at sub-micron and nano-meso scales
XI. Recent developments in dye sensitiesed solar cells
XII. Ceramic toughening

It is clear that there is no shortage of ideas for the topics that are industrially relevant and are within the research aspirations of academic, student and industrial collaborator. Industrial collaboration for this course is not necessary but can be welcome.

3. The literature review skills need to be built up from second year of engineering. In Design and experimental studies modules, students can be required to review state of the art and existing materials. Ability to search through Google, portals such as Web of Knowledge, patents search enhances their skills in developing a customised solution for an open ended problem.

4. The final year individual as well as design project offers a convenient route to undertake a collaborative project with local industries and the student can apply the skills he/she has learnt to an industrially relevant problem. At Swansea University, the final year individual project is worth 30 credits and it spreads over two semesters. T he students are assessed based on a written project report, a oral presentation followed by an oral examination. In the Indian context, students can undertake research based project as described in the category four during their final year project and perhaps complement their efforts by choosing an associated topic for the 'research dissertation' module.

The engineering employers normally show interest in collaboration. The advantage to them is that they save time and money in developing the generic background knowledge on a particular topic of their interest. Normally, group discussions lead to further brain storming sessions leading to the development of fresh new ideas that benefit all stake holders. On many occasions such discussions lead to research collaborations and future research projects. It helps to establish relationship with our industrial counter parts. Another benefit is that this process is sustainable. New problems emerge leading to new student projects and there is continuous enhancement to problem solving skills and contribution to knowledge for academics, students and industrial counterparts.

It is very much possible that final year engineering students come together and participate in a regional student conference where students can present results of their research dissertations to a wider audience. The pdf files can be made available on CD and with hundreds of topics researched and well presented in the form of research dissertation this can be a valuable resource for all stake holders. It can be a meeting place for students, academics and industry colleagues. It is also a better way of engaging with local industries and encouraging them to develop collaborative projects with engineering colleges. Participating students would be the single most beneficiary of this process.

Examples of industrial involvement to enhance employability skills of post graduate students:

The topics discussed in the previous section can almost certainly lead into specific industrial projects that may require full time concentration on a six month, one or two year project. The project can be undertaken in collaboration with a University and the exit qualification of the student could be any of the following MRes/MPhil/Higher diploma/Certificate. The objective could be enhancing student employability skills by placing the student in an industrial environment with academic input on a well defined, well perceived, time bound project. This process is beneficial for the employers as they can test their potential employees without any commitment.

There are many more schemes at the European level that enhances student mobility and collaboration. However, the purpose of this article is to provide examples where state engineering colleges can come together and develop their own space in the category 3 and 4 as described in the first section. One of the most successful, time tested and widely used scheme across Europe is Knowledge Transfer Partnership (KTP). The author is currently leading a KTP project where government, industry and academia come together to develop the associate (student), transfer knowledge to industry and embed industrial best practises/experience into teaching and for the wider benefit of students. One of the reasons of the success of this scheme is that the application process is fair and requires academia and industry to identify measurable benefits for the associate, industrial and academic partner. The scheme has a ring fenced budget for the professional development of the associate and is closely monitored. The overriding criteria is the transfer of knowledge should bring cultural or step change in one of the business processes of the industry and should reflect into growth and profits for the industry. Benefits for SME's are significant. The scheme provides mentoring to the associate and the industry retains all benefits including any intellectual property rights that may emerge from the collaboration. The industry does not have to employ the associate after the project however, most industries offer a job to the associate as the end of the project. The geographic location of the academic partner and industry is an important consideration as the project requires weekly or biweekly meetings between the industrial and academic partner and the associate. This is certainly an area where State Engineering Colleges, State Government and local industries can come together and develop their space in this market. As I have said before, each state in India has maximum one IIT and hence would limit their ability to reach out to local SME's as required as per the KTP spirit. Further information on KTP is available on http://www.ktponline.org.uk/

Other example where local Government can support industry/academia collaboration is the Swansea University led Access to Masters programme that is funded by the Welsh Government (http://www.swan.ac.uk/engineering/latestnews/news/welshschemetodeliverhighlyskilledworkers.php).

Large global organisations like TATA Steel can collaborate with an academic institution to develop a scheme that is partly funded by government to develop post graduate collaborative projects. This can be in addition to many 'year out in industry' or 'sandwich courses' that are currently being offered by many state engineering colleges in India. Another example of such a scheme that Swansea University has developed with TATA Steel is described on Swansea University's website http://www.swan.ac.uk/engineering/research/strip/

The academic advantage of participating in such projects is that it allows academic staff to understand business needs and develop new projects. This can also lead into blue sky research i.e. the research into first two categories that I have described earlier. Benefits reach out to all stakeholders including the society. The research culture at the College of Engineering in Swansea

University is vibrant as it has developed an environment where active participation in research collaborations with industry and students are in all four categories of research described earlier.

I would like to conclude this article with a recently awarded multi-million pound, multi-university ASTUTE project that Swansea University is leading to support Welsh manufacturing industry (http://astutewales.com/en/). ASTUTE project is described as a separate article. Nothing stops State Engineering colleges in India to develop their own solution and provide an environment for students to either excel in India or continue to enhance their skills overseas in Universities such as Swansea University. Swansea University has ambitious growth plans and it is currently the only University in UK with campus by the beach and by 2015, the College of Engineering at Swansea University has plans to move a new location on the beach providing a unique life time experience to its students (http://www.bbc.co.uk/news/uk-wales-south-west-wales-12550913).

ASTUTE

ASTUTE (Advanced Sustainable Manufacturing Technologies) is an exciting project that has just commenced in the *West Wales and the Valleys* area of the United Kingdom. It involves eight Welsh Universities who have come together to form a "Partnership for Prosperity" that will benefit the manufacturing industry of the area.

Located on the western side of the United Kingdom, Wales has a population of 3 million people, covering an area of approximately 20,779 km^2. It is divided into 22 Unitary Authority areas, and 15 of these (collectively referred to as "West Wales and the Valleys") qualify for European Union "Convergence" funding over the period 2007-2013, as their GDP per capita is below 75% of the average GDP per capita of the European Union.

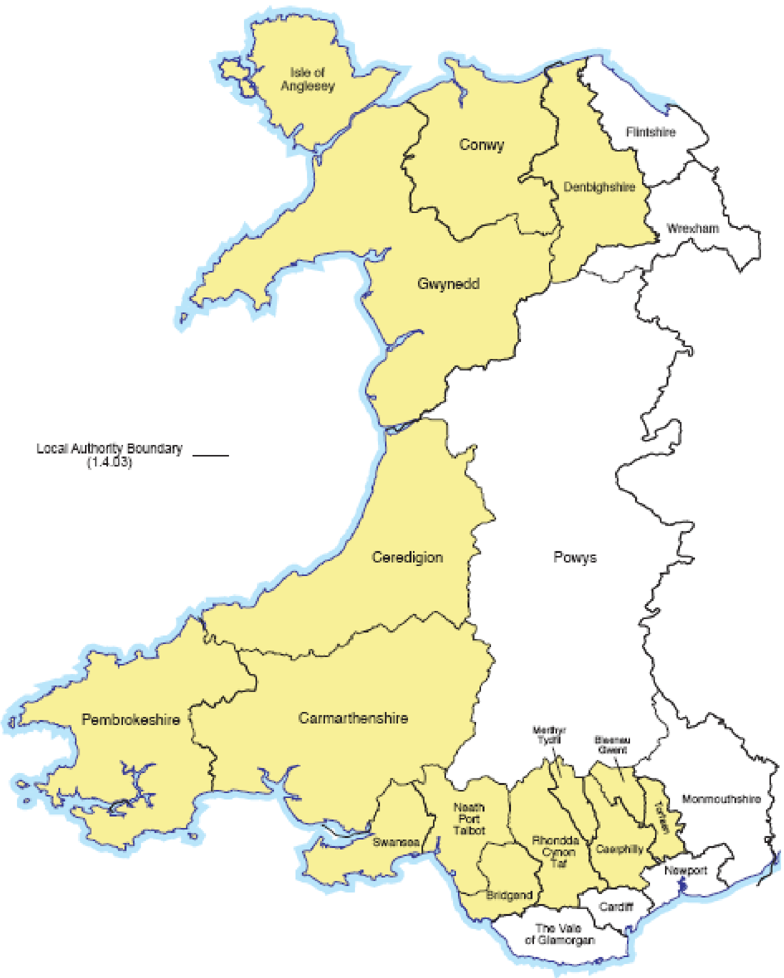

Figure 1 Convergence Area of Wales

“Building the Knowledge Based Economy” is one of the main priorities of the Convergence European Regional Development Fund and this provides opportunities for Universities to work with industry in this area to stimulate prosperity.

ASTUTE is a five year initiative led by Swansea University, in collaboration with the Universities of Aberystwyth, Bangor, Cardiff, Glyndŵr, Swansea Metropolitan, UWIC, and the University of Wales, Newport. It is aimed at helping the manufacturing industry face the challenges of the 21st century. This has been made possible with £14m from the Convergence European Regional Development Fund through the Welsh Government with additional funding coming from higher education institutions. The project will target the aerospace and automotive sectors, as well as other high technology manufacturing, to create sustainable, higher value goods and services and bring them to a global market. It will improve the competitiveness of Welsh companies by applying Advanced Engineering techniques to both the design of products and to the manufacturing process thus securing many jobs and leading to the creation of at least 130 highly skilled new jobs in the sector.

Background

Around 193,000 people are employed in manufacturing and production industries in Wales, with 13,000 enterprises contributing a combined annual turnover of £ 32 billion. Many of these jobs are high skill and high value, being associated with such sectors as Aerospace, Automotive and other high technologies. The vast majority of this activity represents private sector investment brought in to Wales from the rest of the UK together with a significant amount of export income from across the globe. This is the sector that is key to the economic wellbeing of Wales and in particular the Convergence Region, as many other sectors, in particular service industries, derive their income from the investment brought in by the manufacturing sector.

Manufacturing in Wales is exposed to a number of weaknesses and at the same time is presented with opportunities. The weaknesses stem from increased international competition, the relatively slow take up of advanced technologies (often due to the lack of central R&D facilities) and the rather high environmental footprint of manufacturing enterprises. Opportunities include the increased demand for goods and services that can enhance the environment and promote greater sustainability. If our industries can adopt advanced and sustainable manufacturing technologies then the weaknesses can be overcome and significant prosperity can be generated in the region. If not then this income generating sector will decline with the loss of jobs; moreover, the resultant knock-on effects for support sectors will be profound.

Rationale for the ASTUTE project

The aim of ASTUTE can be stated as follows:

To enable the manufacturing industry in West Wales and the Valleys to grow by adopting more advanced technologies, and at the same time improve its sustainability by reducing its environmental impact etc. This will be achieved by a partnership of Universities throughout Wales that will harness the engineering expertise within them for the benefit of the economic prosperity of the Convergence Region.

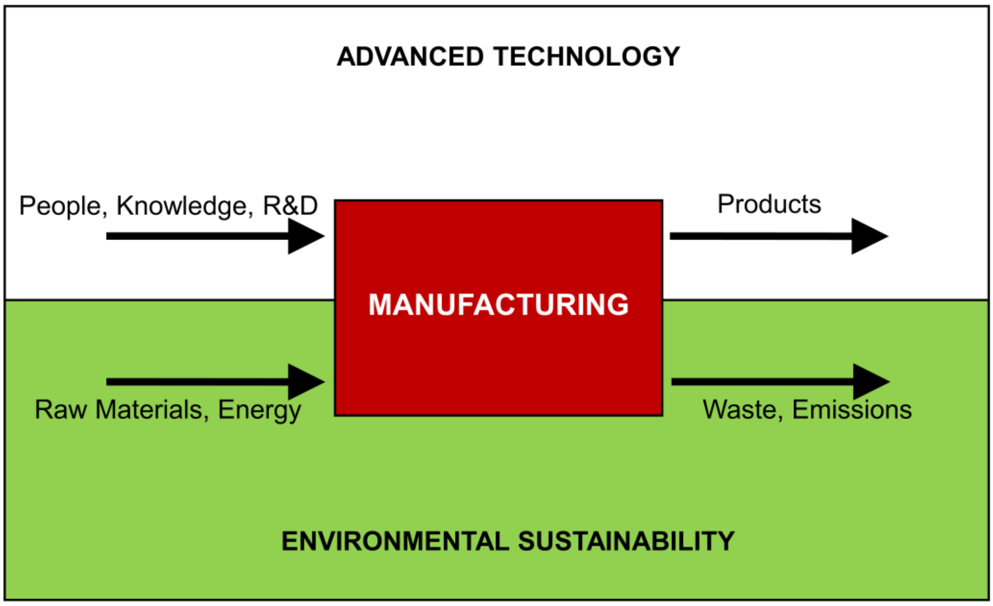

Figure 2 Rationale behind the ASTUTE project

Manufacturing can be considered in the simplest sense to consist of two sets of inputs and two sets of outputs as shown in Figure 2. Inputs can be divided into (i) people, knowledge and R&D activities and (ii) raw materials and energy. Outputs can be grouped as (i) the useful products that are generated from process and (ii) the unwanted outputs of waste material and emissions.

To meet the challenges of growth and sustainability it is necessary to:

- Increase R&D, knowledge and the ability and quantity of the people employed as inputs.
- Increase quality (and quantity) of high-value, knowledge-intensive products output.

- Reduce the quantity of natural resources (raw materials and energy) consumed in producing each unit of useful output.
- Reduce, re-use and recycle waste and minimise emissions of CO_2 and other greenhouse gases.

All of this must be achieved within a 'lean business' framework that requires optimal use of resources in all forms. ASTUTE will address all these issues by drawing on a range of diverse expertise distributed throughout eight partner Universities in Wales.

Project Partners

The Universities participating in ASTUTE are listed below. Funding from the project is used mainly to appoint project officers qualified to at least Masters level in engineering/technology areas appropriate to the existing, recognised expertise at each University.

1. **Aberystwyth University** – intelligent systems and software development.
2. **Bangor University** – opto-electronics manufacturing.
3. **Cardiff University** – in their Innovative Manufacturing Research Centre (IMRC) with respect to lean manufacturing, and the Manufacturing Engineering Centre in terms of prototyping new production processes and routes.
4. **Glyndwr University** - rapid manufacture of composite materials.
5. **Swansea University** – leadership of the ASTUTE project and in computational materials, manufacturing processes, systems engineering technologies, materials characterisation and the application of disruptive manufacturing through additive manufacturing technology.
6. **Swansea Metropolitan University** – non-destructive testing.
7. **University of Wales Institute, Cardiff** - product design, innovation management and medical device development.
8. **University of Wales, Newport** – technology implementation, robotics and manufacture of micro-generation systems.

Extensive work was carried out in the planning stages to identify key academics that could contribute effectively to ASTUTE, and Figure 3 is a summary of this skill set.

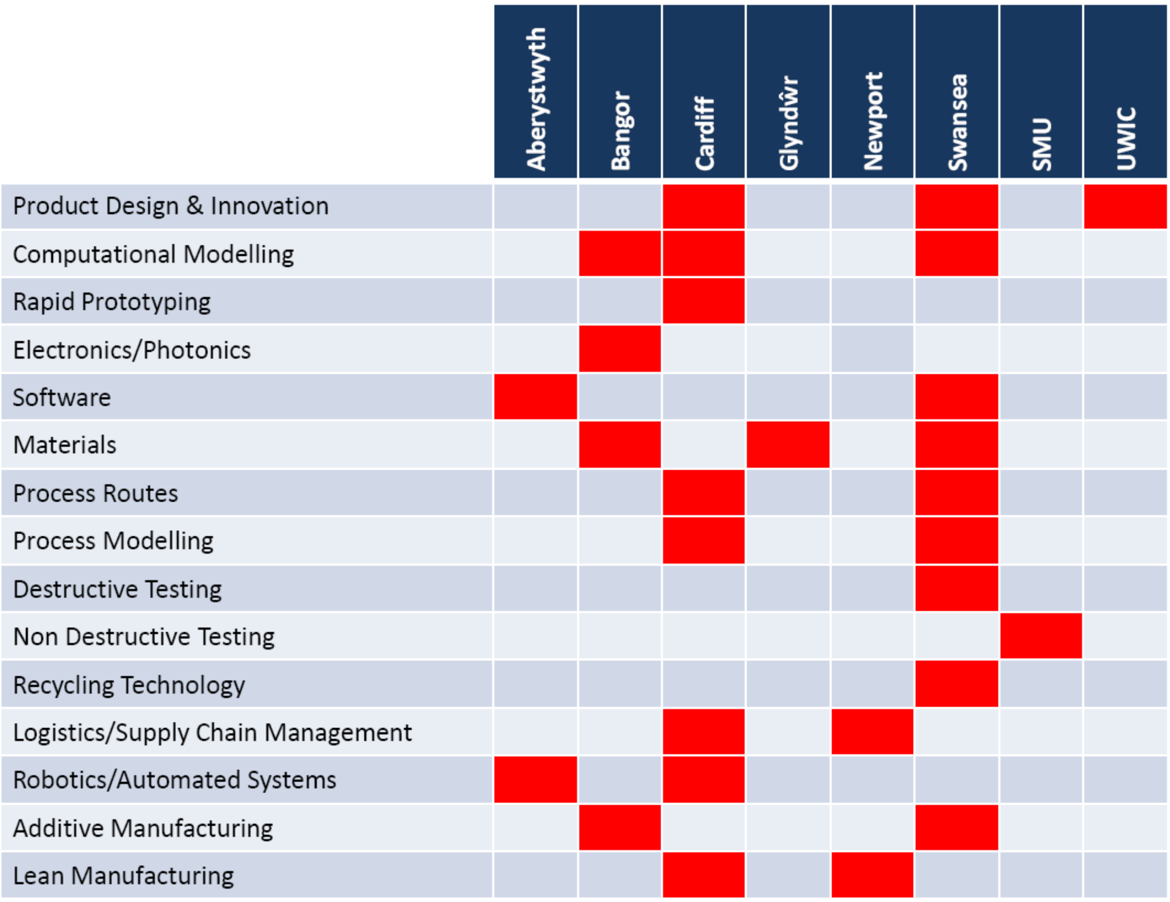

Figure 3 - Skills and Expertise Summary

Mechanism of Operation

The main mechanism of interaction with companies is through Collaborative Research and Development Projects. This involves one or more companies in the Convergence Area and one or more of the ASTUE partner Universities. Here a project is defined with a set of objectives and all parties specify at the outset what their contributions to the project will be. At the same time ownership of the outcomes of the project (including any intellectual property generated) is agreed before the project commences. A full collaboration agreement is then drawn up for all parties to sign.

Such Collaborative Research and Development Projects can be of any duration from a week or two, up to a year or longer. As ASTUTE develops over the five year timescale, it is anticipated that a number of “Cluster Projects” will develop along particular engineering themes, and these will involve participation from several companies and several University partners.

Project Management

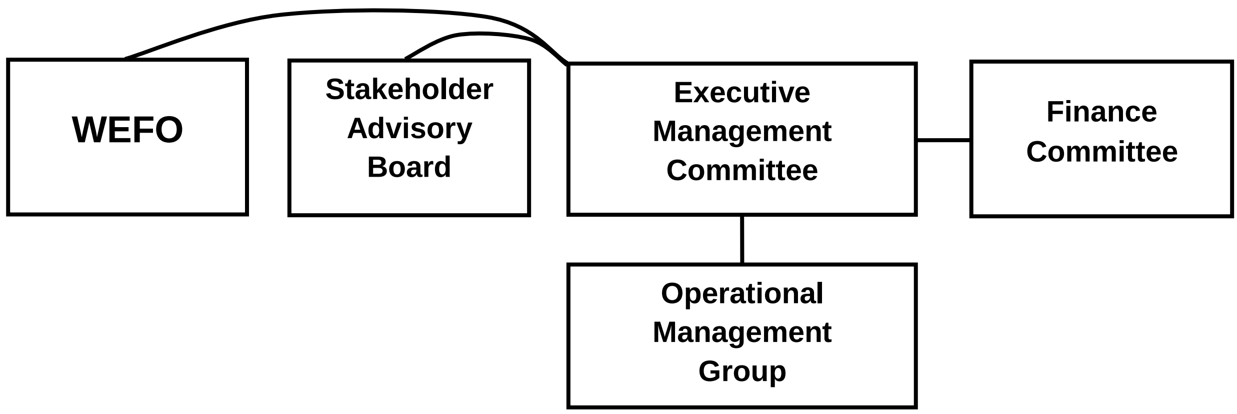

Figure 4 - Management Structure for ASTUTE

The Welsh European Funding Office (WEFO) oversees all European Funded projects in Wales and ASTUTE therefore reports directly to this body, which is itself accountable both to the Welsh Government and the European Union.

ASTUTE is effectively then governed by the pan-Wales Executive Management Committee (EMC). The EMC decides all significant matters relating to the strategy of ASTUTE, including the approval of major collaborative R&D projects, but excluding those relating to financial allocations (which must be approved by a Finance Committee described below). The EMC comprises representatives from all partner HEIs across Wales, and is chaired by a nominee from Swansea University. It meets every 3-4 months, and reports directly to WEFO. It also reports to, and takes advice from, the Stakeholder Advisory Board.

Day to day running of the ASTUTE project is then be carried out by the Operational Management Group (OMG), which comprises members from Swansea and Cardiff Universities.

The Finance Committee will be convened to deal with any proposals that may arise from the Executive Management Committee or from the ASTUTE Director which have an impact on the overall financial arrangements of ASTUTE.

All stakeholders, internal and external, are invited to participate in the Stakeholder Advisory Board. The frequency at which this group meets is approximately every six months. It includes representatives of local manufacturing industry as well as nominees of the Vice-Chancellors of each partner University.

The Project Chairman is Professor Mark Cross of Swansea University and the Director is Professor Johann Sienz. Dr Ceri Davies is the Project Manager.

Prioritisation of Potential Projects

To maximise economic impact in the area of West Wales and the Valleys, a number of metrics have been specified to measure the success of ASTUTE. These are as follows:

- Enterprises assisted
- Collaborative R&D
- Innovation centres and R&D facilities developed
- Gross Jobs created
- Enterprises Created
- Investment Induced
- Enterprises adopting or improving Equality Strategies and Monitoring Systems
- Enterprises adopting or improving Environmental Management Systems
- Products, processes or services registered
- New or improved products, processes or services launched

In addition to the scientific quality of the proposed R&D work, all potential projects with companies are first assessed for their ability to deliver against these metrics. Projects are then approved or rejected on this basis.

A set of overall targets have been set for each of these metrics for ASTUTE, and the Executive Management Committee monitors progress against these targets.

Progress to Date

At the time of writing, ASTUTE is still in the early stages. Having commenced in May 2010, we are now at the stage where most of the project partners have recruited the project officers for their technical teams. A number of Collaborative R&D have commenced and have resulted in a number of new products and jobs created in manufacturing companies in West Wales and the Valleys. The project team are confident that ASTUTE will have a significant impact on the economy of the area in the years to come.

Further details about ASTUTE can be found on the project website, www.astutewales.com

About the Author:

Dr Rajesh S. Ransing has completed has BEng in Mechanical Engineering at Govt. College of Engineering, Pune in 1989 and ME in Mechanical Engineering at IISc Bangalore in 1992. Since 1992, he has continued an uninterrupted research at Swansea University since his PhD.

He holds one US patent and 40 papers in international journals with equal number of papers in conferences. He is a co-author of a John Wiley book titled “Fluid Properties at Nano Meso Scales” (238 pages). He has successfully supervised 6 PhD students, currently supervising 6 PhD/EngD students and also supervised number of post doctoral researchers. He has led number of research projects with over one million pounds of research money funded by number of sources such as EPSRC (Engineering and Physical Sciences Research Council), Knowledge Transfer Partnerships and Collaborative Industrial Research Projects on foundry process optimisation related topics. The EPSRC funded research was identified by EPSRC as tending to internationally leading. He has also experience of commercialising his EPSRC funded research via a spin out company. In a recent landscape document EPSRC identified his effort as an example of ‘Greatest User Collaboration’ and written a success story on its website http://www.epsrc.ac.uk/newsevents/casestudies/2007/Pages/scrapwaste.aspx