

Enhancing learner capabilities in undergraduate science programmes through small-scale research activity: teaching of the subject ‘agricultural ecology’

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Three academics involved in an innovative undergraduate programme in ecological agriculture in Australia, present this article as one possible response to a recent discussion in this journal on aspects of Indian universities’ approaches and track record in providing training in science and technology (S&T) research. We do so not to imply in any sense that our approach to research skill-ing of undergraduate students could be transplanted into the Indian context; we are acutely aware of the momentum within any national higher education system to frame the educational context, as it may have been framed for generations. We believe, however, that despite the inbuilt reluctance of an education system to accept innovation and incorporate changes readily, new ideas can be tri-alled by individual academics: they can achieve a new mix, reconfigure the learning challenge, to give their learners a well grounded and relevant induction into the ways of their respective chosen professions, including a career in S&T. The specific example used in this article is a third-year core subject in the Bachelor of Land Management (Ecological Agriculture) programme of the Uni-versity of Sydney, Orange, and how that subject sits within a curriculum-wide capability education approach.

Keywords: Academics, agricultural ecology, small-scale research activity, teaching, undergraduate science pro-grammes.

SEVERAL observations and comments expressing concern on the quality of university education, teaching of science in the universities, and research efforts in India have been regularly appearing in *Current Science*¹⁻⁷. Recently, Lakhotia⁸ voiced his concern referring to the quality of learners pursuing basic science programmes and on the quality of training received by them. Although targeted at development of world-class skills in science and technology (S&T), Lakhotia’s diagnosis sees the problem as one that extends into many diverse areas of university organization and practice, and his prescription is to make changes across this broad front. We do not intend to enter the discussion at this plane; rather, we wish to highlight a possible pathway for developing world-class researchers to secure the future of S&T.

In our undergraduate teaching–learning practice, we have incorporated rigour through ‘capability’ (*sensu* graduate attributes) building in learners. To achieve this, we have

integrated small-scale research efforts in undergraduate programmes, thus encouraging self-directed learning. We recognize that modern university education emphasizes on building capabilities in undergraduate learners, so that they will be able to (i) obtain relevant data, as much in-dependently as possible, that will be appropriate to the circumstance in which they will be learning, (ii) learn from that data through comparison and contrasting, (iii) offer new interpretations from such a learning, and (iv) present the learned information in a professional manner. By making capability building work well in undergraduate learning, the learners will also be able to demonstrate appropriate decision-making skills and to make right decisions under difficult, unanticipated, and even trying ‘real life’ situations. Criteria for employment also reinforce, when recruiting fresh graduates, on capabilities such as being able to demonstrate appropriate decision-making skills and to make right decisions under difficult situations. Employers seek whether the new undergraduates can demonstrate necessary power to enhance the productivity of the industry through quality performance coupled with high level of efficiency. In contemporary understanding of higher edu-

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cation, performance and efficiency are usually measured in terms of attainment of greater hands-on skills and achievement of higher order intellectual capabilities in the learners⁹. The principal goals of any present-day institution of higher learning, generally, are that the institution (i) stands for a value of providing the right and appropriate opportunities for education, (ii) possesses the sensitivity to recognize changes and pressures in the society and respond to those changes and pressures in a meaningful way, and (iii) facilitates the development of intellectually capable and flexible human resource¹⁰. Such goals remain dynamic because they change with the constantly changing social context. It is the changing social context that necessitates the integration of research capabilities in learners in higher education, because building research capabilities ensures learner independence during the study period; learner independence, in turn, provides an opportunity to the learner to develop the skills to make right decisions at right times. The abilities to (i) recognize a problem (or an issue), (ii) evaluate the strengths and weaknesses of matters around the problem, (iii) design appropriate methods to deal with the problem after a systematic evaluation of the strengths and weaknesses, (iv) test the methods designed using the right tools, (v) arrive at meaningful conclusions, and (vi) offer at least one viable solution to the identified problem from the orderly sequence of steps that accelerate maturity of mind and thought in young learners and thus equip them with necessary problem-solving skills and capabilities to make right decisions at appropriate times, which are considered critical in future employment. More importantly, through such a process, the learner also acquires a few additional, desirable capabilities, such as being able to communicate his/her conclusions and solutions to appropriate audience in a professional manner.

Designing an academic programme for learners enrolled into higher research degrees (e.g. Honours, M Phil, Ph D) is a relatively easy task. However, effective and efficient incorporation of research skills into the teaching-learning activity of learners in undergraduate and course-work Masters programmes is generally difficult, even for experienced academics. Difficulty in such circumstances usually arises out of several constraints; the key constraints being: (i) unlike exclusively research-based higher degrees, undergraduate and course-work Masters programmes attract large numbers of learners; (ii) constantly shrinking resource base with progressively declining commitment and support from governments and industry; (iii) an extraordinary mismatch between employer needs on the one hand and higher educational teaching-learning effort on the other. The numbers constraint is probably the most critical driver for the practice of many university teachers adapting Fordism¹¹ to 'manufacture' stereotypic graduates, who neither have the ability to think for themselves nor have the ability to demonstrate their problem-solving skills and creative thinking.

Context of education at the Orange campus of the University of Sydney

The Orange campus of the University of Sydney (USO), established nearly 30 years ago as an independent agricultural college, meets the higher educational needs of rural Australians, within the specific domain of 'rural management', dealing with subjects and experiences that are relevant to youth and employment opportunities in rural Australia¹². Majority of the learners are from the state of New South Wales; nonetheless, a thoughtfully designed distance-education programme meets the needs of learners not only from other states of Australia, but also from overseas. Education at USO includes Bachelors and course-work Masters degree programmes and research Masters and Doctoral degree programmes focusing on imparting and developing multidisciplinary capabilities linking sustainability and management by effectively blending the principles of science and the tenets of management.

Our capability approach to learning seeks to equip learners to take responsibility for their educational, personal and vocational development, and enables the institution to provide the right opportunities and appropriate environments in which the learners achieve their goals; this approach also reinforces the development of an independent learner, so that the learner experiences the truest context of academic freedom^{13,14}. USO's educational effort reinforces capability as an instrument for developing a justified confidence in one's own ability to (i) take appropriate and effective action, (ii) communicate effectively, (iii) collaborate with others, and (iv) learn from others' experiences¹⁵. USO distinguishes competency-based education from capability-based education, by seeing competency-based education as one which generally arises out of economic criteria and necessities. USO sees competency being synonymous with 'dependent capacity' – an ability to handle familiar problems in familiar contexts – whereas capability is synonymous with 'independent capacity' – an ability to handle unfamiliar problems in unfamiliar contexts.

USO has developed a set of nine capabilities for effective translation and implementation in every subject taught in Bachelor degree programmes, which are listed here: (i) the ability to apply creative and critical thinking processes, (ii) the ability to communicate with people, ideas, texts, media, and technology, (iii) the ability to work with, manage and lead others in ways in which their diversity and equality, and which facilitate their contribution to the organization and the wider community, (iv) the ability to acquire and apply appropriate management, technical and practical skills and knowledge, (v) to display a confident but realistic judgement of one's capacity to achieve, (vi) to recognize and accept continuous learning as being central to one's capacity to realize potential, (vii) to hold personal values, beliefs and ethics necessary for a sustainable and healthy planet, (viii) to hold a perspective which acknowledges local, national and international issues, and

(ix) to value a citizenship role which is connected to and responsible for the social, environmental, political and economic systems in which we live¹⁵. Cochrane *et al.*¹⁵ explain the terms used in the design of the USO's capabilities and their specific contextual meanings. Whenever a new teaching subject is being planned, the subject development team makes every effort to incorporate at least six of the nine capabilities as the generic teaching and learning outcomes of the newly developed subject.

Drivers of research-led teaching in undergraduate programmes

We at USO perceive research training as a key driver in undergraduate programmes, because all the identified capabilities refer to research-led teaching approach either directly or indirectly; capabilities (i), (ii), (vi), (vii), (viii), and (ix), however, emphasize research training. We also recognize that research training includes attainment of 'transferable' skills, which include the theoretical knowledge and practical abilities to explore the existing opportunities and create new opportunities, to develop action plans and effectively network with appropriate sets of people, to be able to make right decisions, to negotiate, to cope with uncertainty, to focus on development and growth, and to transfer knowledge and experience effectively. Transferable skills, in our context also include 'self-reliance skills' such as self-awareness, self-promotion and self-confidence. Several of the senior-level undergraduate subjects taught at USO also envisage the same process. We illustrate this point here taking the subject 'agricultural ecology' (USO # RMAS 3504)* as an example. This

*Aims and scope of agricultural ecology (USO # RMAS 3504): Unsustainability of agricultural practice in principle arises out of an overt dependence on a huge volume of high-energy inputs based on fossil fuel. Efforts to mask the deterioration of agriculture's foundation with higher yield and GNP cannot continue in the long run, especially because of the staggering increase in human population and consequent changes induced in the climate and in natural ecosystems by human activities. Keeping these points in view, teaching of this subject will aim at (i) clarifying the ecological context of agriculture (a) by recognizing and validating the agricultural system as an ecosystem, and (b) by explaining the ecological processes that operate in agroecosystems; (ii) addressing the strengths and weaknesses of issues relative to interfacing between humans and agricultural ecosystems, (a) by explaining the application of agroecological principles in achieving sustainability; (iii) describing the methods of designing sustainable agroecosystems. The subject concludes with an open-ended question: how can we operationalize an efficient ecological management of agriculture by creating a multi-focal, multi-criteria and multi-scale performance space?

Expected learning outcomes: On completion of this subject, the learner will be able to (i) explain the concept of agroecosystem and ecological principles on which natural and managed ecosystems are understood; (ii) outline the basic differences between a natural ecosystem and a managed ecosystem (e.g., agroecosystem); (iii) apply the theory and principles of agricultural ecology in a review of the management of a farm, and (iv) reflect on the learner's own needs, biases and emerging position on appropriate directions for agriculture.

subject is offered to third-year learners of undergraduate programmes.

Methods used in research-led teaching in agricultural ecology

As in most subjects offered at USO, the physical hub in agricultural ecology is the printed learning guide, which comprises an outline structure of the semester-long learning programme, a series of study topics, copies of essential readings, and suggestions for additional reading. In agricultural ecology, learners use the resources in the learning guide, the subject's website (WebCT[®]) as well as the media and personal observation and experience as the raw material for learning. They participate in discussion with the subject teacher and their peers both during the residential school and on-line. It is out of all these stimuli that they engage in the research challenge of the assessment tasks and develop their own knowledge in this subject area.

Dedicated assignments reinforcing small-scale research

The magnitude of effort to be invested into the assignment tasks is fully recognized by the subject teacher and the educational developer, who work as a team in developing the study material and the overall curriculum. The design of the assignment tasks is such that it encourages the learner's individual effort and self-study through practical field experience in dealing with a current real-life issue. The following explain the point in reference. The major assignment task 'Property Planning Report' within agricultural ecology (offered in the third-year study in the Bachelor of Land Management programme) includes an overall weightage of 65% marks. For reasons of convenience, it is divided into two sub-assignments: (a) Profiling the current operation (weightage 25%) and (b) agroecological management plan (weightage 40%). Learners submit sub-assignments (a) and (b) one after the other in a specified timeframe and they are marked independently. Learners receive a detailed set of guidelines (see below) in advance, thus enabling them clarity of purpose to achieve their goals in this assignment task:

- (i) Learners should select a conventionally managed farm, which should be a monocultural enterprise of manageable size. The enterprise can either be of annual cash crops or horticultural perennials or a tree plantation. Most importantly, the chosen farm should have been managed conventionally at least for the past 30 years.
- (ii) Learners are to imagine that the manager of the chosen farm recognizes the learner as a consultant and

therefore seeks help from the learner to prepare a management plan so as to convert the farm from conventional management practice to an agroecological management practice, say, in ten years.

- (iii) In such a scenario, sub-assignment (a) above will describe what exists currently in the chosen farm and will be presented in a manner acceptable within professional reporting style; sub-assignment (b) will build on the data and information the learner has obtained through his/her 'research' (reported in sub-assignment (a)) and encourage the learner to propose a new and viable management plan for the same farm with a distinct agroecological focus.

Research components in sub-assignment (a) include (i) extraction of information on the biophysical factors of the property and the landscape in which the property is located through desktop research and Internet searches; (ii) scientific description of the chosen farm's current management practice (e.g. details pertaining to irrigation practice, nature of chemicals applied, frequency of application and application regimens of such chemicals); (iii) scientific description of the chosen farm's past management practice (e.g. details pertaining to irrigation practice, nature of chemicals applied, frequency of application and application regimens of such chemicals); (iv) scientific description of the chosen farm's economic performance; (v) scientific description of the biotic and abiotic factors within the farm and the catchment context in which it is situated. Description of biotic factors will be done by the learners following standard ecological procedures for assessment of populations of organisms; learners of agricultural ecology would have learnt these methods in the previously completed subjects, 'Biological Environment' and 'Applied Ecology'.

Based on the feedback provided by the subject teacher on assignment (a), the learner then completes sub-assignment (b), first by incorporating the modifications and changes suggested in sub-assignment (a), and revises this part for integration into assignment (b). The revised part will constitute the 'introduction' for assignment (b) and will thus be the context for the key task identified in sub-assignment (b), which is the development of an agroecological management plan for the chosen farm. At this stage, the learner is encouraged to keep the biophysical, economic and sociological strengths and weaknesses of the chosen farm in full view and address the question of achieving sustainability in the chosen farm by dealing with (i) characteristics of soil, (ii) hydrogeological factors, (iii) biotic factors, (iv) ecosystem-level characteristics, (v) farm profitability, and (vi) social and cultural environment, identified as the key parameters in agroecosystem development and sustainability¹⁶. To deal with the question 'How sustainable will the proposed plan be?', the learner is encouraged to:

- (i) analyze the context of the agroecosystem by relating the social and natural systems of the chosen farm;
- (ii) relate the analysis thus made (item (i)) with the chosen farm's structure and functions by identifying and characterizing the social and ecological components;
- (iii) relate the analysis thus made (item (ii)) to characterize the indicators of sustainability in the chosen ecosystem (farm);
- (iv) predict the possible efficacy of the management plan by describing the condition of sustainability.

Overall, the task emphasizes on self-learning skills in learners, with limited inputs from the subject teacher, through a small-scale research study and the above example illustrates the point. Given the limitation of time (one semester programme, with a functional working period of 16 weeks), the learners go through an exercise of trialing a study and achieving measurable outcomes, by adapting hands-on research trials as well as extraction of relevant data through desk-top research. Every effort has been made to minimize desktop research and maximize hands-on field experience.

Importantly, the texts of sub-assignments (a) and (b) need to be presented in a professional manner with appropriate illustrations, tables of data, and explanation of any analytical methods used, supplemented with 'in-text' and 'end-list' sections of the cited references. To encourage a professional style in presentation, every learner is provided with a copy of the *A-Z Style Guide*¹⁷ prepared exclusively for our learners based on the style for language use prescribed by the Australian Government Publication Service (Canberra).

Marking is done taking into consideration the viability and sustainability of the new management plan, evidences provided in support, originality and creativity displayed in the assignments, evidence of extensive reading and conformity to professional presentation skills. On recognizing any possible misappropriation and misbehaviour, the marker will levy penalties.

During the three years of study to obtain an undergraduate degree, learners maintain a portfolio of evidence in relation to the nine capabilities referred to earlier. In Year 3, learners submit the portfolio in evidence of achievements in relation to each of the nine capabilities. An industry representative and an academic jointly assess the portfolio evaluating the quality of submitted evidences in the context of learning achieved. A pass in the portfolio component is compulsory for graduation. While learners of agricultural ecology develop capabilities (i), (ii), (vi), (vii), (viii), and (ix), those capabilities then get reinforced and further developed as learners study 23 other subjects with similar capability expectations. The accumulated evidence to date¹⁸ demonstrates that learners are emerging with greater capabilities to meet readily complex work situations and to think critically about world issues.

Conclusion

We have recently read various commentaries in this journal touching on the quality of university education, the teaching of science in the universities, and research efforts in India. We have particularly noted the article by Lakhota⁸ in which present-day university culture in India can be seen as hampering further progress of S&T education in India.

We have written this article out of a conviction that cultural change within an academic institution can begin in modest ways and in unrecognized corners of a university's curriculum, especially in undergraduate teaching-learning programmes. While there is no doubt that there can be heavy constraints on cultural change in universities emanating from national governments and their funding priorities, it is imperative that concerned academics at every level within an institution recognize that each of us possesses *some* room to move. We are aware that we may not be able to renew an institutional culture by ourselves or even together, but it is certainly possible to transform our individual teaching approach and make a difference in the academic and personal development of learners. It is productive, and instructive to imagine a bottom-up approach to institutional renewal.

What we have done in this article is to present the story of one Year-3 subject in a Bachelor's degree programme offered at USO. Despite the foreignness of our situation, we felt that sharing our teaching approach may provide an option for those who are presently disheartened by the scale of challenge, especially by staggering numbers.

Our over-riding intention in this article has been to provide readers with a sense of a two-tiered educational design: the macro-design of our capability education approach, and the micro-design incorporating a more detailed application of our curriculum-wide priorities at the level of an individual subject. We have covered considerable ground in describing the purpose, design and operation of agricultural ecology. Our impression to date is that this approach is delivering graduates who leave us not only with a moderate level of competence in scientific research, but also be capable enough to enter their chosen careers with a principled view of their roles as professionals and global citizens.

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