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# Improving Engineering Students' Design Skills in a Project-based Learning Course by Addressing Epistemological Issues

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Project-based learning (PBL) requires a shift in epistemology on the part of the teacher/lecturer. What is sometimes less acknowledged is that it also requires the adoption of a matching epistemology on the part of the student. To succeed in a student-centred environment students should see themselves and peers as valid sources of knowledge, integrate concepts, view knowledge as tentative, justify decisions in a rational way, accept they can improve as learners and that learning is a continuous process [1]. Enactment of such an advanced epistemology on exposure to student-centred learning should not be assumed to spontaneously occur. Rather, the learning environment should facilitate such development during the college years. In this paper we outline the history of research into personal epistemology starting with the stage models (Perry's model of intellectual development [1], Reflective Judgment Model [2], Women's Ways of Knowing [3], Epistemological Reflection Model [4]), moving on to the multi-dimensional [5, 6] and finally outlining the framework of epistemological resources model [7, 8]. The ontological and epistemological differences between these are discussed. Based on the resources model we investigate the influence of personal epistemology on aspects of design in a PBL module delivered in the second year of a three year electrical engineering technology programme in a third level institute in Ireland in which stu-

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dents design and build a weather station. Qualitative data were collected through one to one, semi-structured interviews with five participants and a focus group with six other participants. A questionnaire, Epistemological Beliefs Assessment in the Physical Sciences [EBAPS 9] was completed by a majority (n=32) of the class. The dimensions of epistemology we explored are self as a source of knowledge, concepts of justification and structure of knowledge, these being key epistemological issues for project-based learning. Qualitative differences in the enactment of these epistemological issues were observed among a sample of students who were interviewed. For one student, Oliver, certainty in knowledge was not expected in the context of the system he designed; compared to his peers he demonstrated a relatively independent approach to design and justified his product based on a well considered and comprehensive set of criteria. Oliver achieved a high score in the tutor's assessment of his contribution to the learning process. His enactment of personal epistemology seems very appropriate for PBL. The process mark assigned by the tutor supports conclusions drawn from the interviews in terms of the differences between Oliver and another student, Sean. Oliver's enactment of personal epistemology achieved a higher process mark. Sean chose not to look to himself for direction in design, instead searching the internet for solutions to adapt and taking direction from his peers. He justified his design based on a limited set of criteria. However, he appeared to have sufficient understanding and motivation to be independent but did not enact such independence in this module and achieved a low mark on his contribution to the learning process. If Sean were to enact a more advanced epistemology he could engage more with the module, develop better designs, produce better artifacts, improve his grade and become a better engineer. Through continued exposure to PBL with feedback on the learning process Sean could be encouraged to enact more appropriate epistemologies more often. The reflective reports prepared by the students could be more targeted to encourage change. In Sean's case, he could be asked to reflect on ways he justifies decisions by recalling good examples from any context in his life and exploring how he could transfer these to the context of engineering. Such an approach has been shown to be effective in creating change in conceptual understanding [10]. ■

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