Pre-service STEM educators' perceptions of the design activities to inform educational practice (Research to Practice - Strand: Other)

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A comparative (pre and post) analysis of pre-service STEM educators' perceptions of designing activity to inform educational practice (Research to Practice - Strand: Other)

Abstract

The role of design based STEM education is to foster and develop a range of transferable skills, values and knowledge which will be appropriate in solving problems[1]. Conventionally, these skills are promoted through design based learning tasks where students conceive, create and communicate their solutions to the problems posed[2]. Promoting a linear approach to a task which is dynamic and fluid stifles the creative ingenuity of students and presents unauthentic evidence of the design process[3]. In developing higher order thinking skills, through the design task, students are encouraged to record their design evolution primarily for the purpose of assessment.

A stratified sample (*n*= 15) was taken from a cohort of first year undergraduate students enrolled on a four year initial technology teacher education programme. The study investigates the beliefs and values held by the students regarding the value they place on learning through design and the value they place on the stages of the design process. Students created their own personal conception of a theoretical framework that captured the stages and functions of their personal design journey. The frameworks were modelled by students, based on their beliefs pre and post their engagement in a semi-open design based task. The results presented highlight a shift in the value placed on the process of learning through design from students' initial understanding and their experience of designing following their engagement in the design task.

Introduction

Design based technology education as a catalyst for 21st century skills is seen in its educational goals, through promoting the development of students as autonomous, creative, reflective and innovative learners[3]. The development of these characteristics through design based technology education, it is envisaged, will equip students with a set of transferable skills which can be adopted to address specific problems in real-life contexts outside of formal educational settings[4]. Contemporary values underpinning the nature of STEM based subjects' places greater focus on preparing students to be active participants in society. It is therefore the role of STEM educators to motivate students to explore and establish what is of value to them and in turn to increase the capability of students to critically engage in and have an impact on society[5, 6].

In Ireland, proposed change at lower post-primary level (Junior High, 12-15 year olds) aims to move towards a more design focused curriculum, where the focus of education is on the needs of the student to develop competencies and not driven by the need to perform in externally mandated high risks assessment. The hegemonic behaviourist model where the focus is on examination success, as opposed to the goals of design based technology education has led to the narrowing of subject content to that required in state examinations. The "standards movement"[7] fails to acknowledge the broader learning desires of a subject. This influence can be seen in student design project work where an over reliance on a linear model of design is evident. Atkinson argues for high levels of cognitive processes to be developed students should record and report on the learning activity simultaneously[2].

By having placed university students at the core of a design based task, this paper, investigates the perceptions held by students towards the design process pre and post their engagement with a semi-open design task. Through this investigation the role of a structured and functional approach to design based technology education will be investigated.

The role of design in education

The role design based activities play in education is influenced greatly by the nature of the task posed to students and also by the philosophical view point of educators and curriculum designers. Conventionally, the primary method of instruction in technology classrooms is based upon a project based model[6, 8], where the process of design is outlined by a series of stages from design conception to realisation. Approaching the learning activity in this manner creates a philosophical conflict, where on one hand designing is seen as "a creative, branching, iterative, and cyclical process based on multi-disciplinary dimensions" and other contrary views are functional where the requirements of "products-production" need to be met[9].

A study conducted by the Assessment and Performance Unit (APU) at Goldsmith College, University of London, led to the development of a descriptive, iterative model of design and technology, illustrating the complexity of the design process, integrating the internal personal conceptual ideas of the student and the external representation of their ideas[6]. The design process is a highly intellectual and personal process, which reaches past behavioural, linear and cyclical models. It requires the application of a series of higher order thinking skills and the ability to transfer understanding from experience to new scenarios[10]. The work of the APU was concerned with understanding this process and engaging in the "why and how learners chose to do things than in what it was they chose to do"[6].

Task Design

Learning in design based technology education characteristically takes place through a design task which engages students in an activity where the students design, create, reflect and report on. This pedagogical approach is capable of finding a fine balance between the intended learning outcomes of the teacher while allowing the student the autonomy to explore and express their individual needs and experience[8]. A move from teacher managed to more permeable student centred activities allows autonomy, which Kimbell (1994) argues, is determined on students procedural knowledge coupled with the expectance that project work would place ever greater demands on the students[8].

Providing the students with a medium through which they can effectively reflect on, capture and present evidence of their learning for assessment is necessary if the potential of the learning task is to be fully appreciated.

Capturing student learning

Traditional means of capturing evidence of student learning is through a design based portfolio. The role of a student portfolio is to provide a student with a medium through which they can collect, reflect, select and present evidence of educational development overtime[11]. The principles supporting the development of student portfolios is to capture educational substance, deep learning, while supporting the educational achievement and demonstrating evidence of personal growth and academic competence for assessment[12]. Portfolio building is a process rather than a product, where the importance is placed upon the presentation, by students, of critical thinking, reflection and the progression of student understanding and academic development[13].

Contemporary models of portfolio building have moved towards an electronic portfolio (e-portfolio), designed as a modern variation of the traditional paper-based model. Similar in purpose, an electronic portfolio is "a digitised collection of artefacts including demonstrations, resources and accomplishments that represent an individual, group, or institution"[14]. An e-portfolio has a number of fundamental differences which distinguishes it from a traditional portfolio. The multi-modal potential of an electronic portfolio provides for a richer palette of media from which the student can choose to represent their learning[15, 16]. Additionally, the digital nature of the e-portfolio allows students to capture, construct and present evidence of their capability and learning throughout the learning activity[17]. It presents students the opportunity to monitor and feature evidence of their learning in real-time and in response to key learning achievements as they happened. Reporting on the design process in this way removes the "post-task burden on learners" to reverse engineer "a sanitised account of the process"[18].

In this context, this paper explores the importance students place on different aspects of their learning when engaged in the process of learning through design. The details of the study are further outlined in the following section.

Methodology

Approach

This research is formulated on the basis of a study conducted with tertiary students at the University of Limerick. The students are enrolled in two initial technology teacher education programmes, based on a concurrent model of teacher education, the Bachelor of Technology in Materials & Architectural Technology with concurrent teacher education and Bachelor of Technology in Materials & Engineering Technology with concurrent teacher education. These concurrent initial technology teacher education courses scaffold the development of subject specific skills and pedagogical skills required to teach effectively at post-primary level in Ireland (ages 12-18, junior high to high school). This paper presents the outcomes of an exploratory study investigating the beliefs and values held by student teachers in relation to the importance of learning through design and the importance which they place on the different stages in the design process. The results presented explore the shift in importance placed on each stage by the students both pre and post their engagement with a semi-open design task.

Participants

This study was undertaken with year one students participating in both of the initial teacher education (I.T.E.) courses outlined. As part of the syllabus for semester two, year one, on both I.T.E. programmes, students participate in a module where the focus is on students developing fundamental practical skills, developing theoretical knowledge and challenging students epistemological beliefs regarding the value of design based education. One element of the module assessment engages students in a semi-open design task. The design-based project comprises of a number of important features:

1. The students are issued with a semi-open design brief
2. Students must produce a physical artefact
3. Students are required to evidence their learning and capability through a non-criterion referenced electronic portfolio.
4. Student's e-portfolios are holistically peer assessed peers using Adaptive Comparative Judgements[17] software[1]. This process involves students defining their own criteria for assessment.

Part of the module structure was designated to seminar sessions for one hour per week. During this time students were introduced to fundamental pedagogical practices and underlying principles of their subject area through focus groups, experimentation, modelling, exploration and student centred reflective activities.

Design

This research was conducted with all I.T.E. students as one aspect of timetabled seminar activities. Students were set a task to develop their own conception of a theoretical framework which captured the stages and functions of design. Students then created a model to physically illustrate the stages of the design process and the importance which they would place on each. This task was conducted in week three (pre-test) and week ten (post-test) of the module. Structured in this manner students completed the task both pre and post their engagement with the student centred design project. As not all of the students submitted entries in both rounds of the study, the sample taken (n = 15) represents a stratified sample of students whose work was presented in both rounds.

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[1] Adaptive Comparative Judgement (ACJ) is based on the Law of Comparative Judgement [17,19]. The approach uses an ACJ model of assessment where comparisons of students work are made using a holistic judgement on the quality of the evidence of learning presented by the student. This holistic judgement requires the judge to have an understanding of what is better or worse in terms of the required capability[17].

All students were assigned similar tasks in week three and week ten of the seminars. In week three as outlined above students were asked to develop their own conception of a theoretical framework which captured the stages and functions of design. During this process no criteria were set and students presented the stages of design based on their epistemological understanding of the design process. In week ten students were asked to complete a similar task based upon their understanding of the importance of the stages of design following their engagement with the semi-open design task. During this round of investigation students were given specific stages, identified following initial analysis of the data from round 1. The stages provided to the students were:

1. Analysis of Design Brief
2. Research and Investigation
3. Design Evolution
4. Realisation
5. Evaluation

To physically represent the stages of the design process students were provided with modelling material as outlined in figure 1 below. Schematic examples of solutions created by students can be seen in figure 2 below.

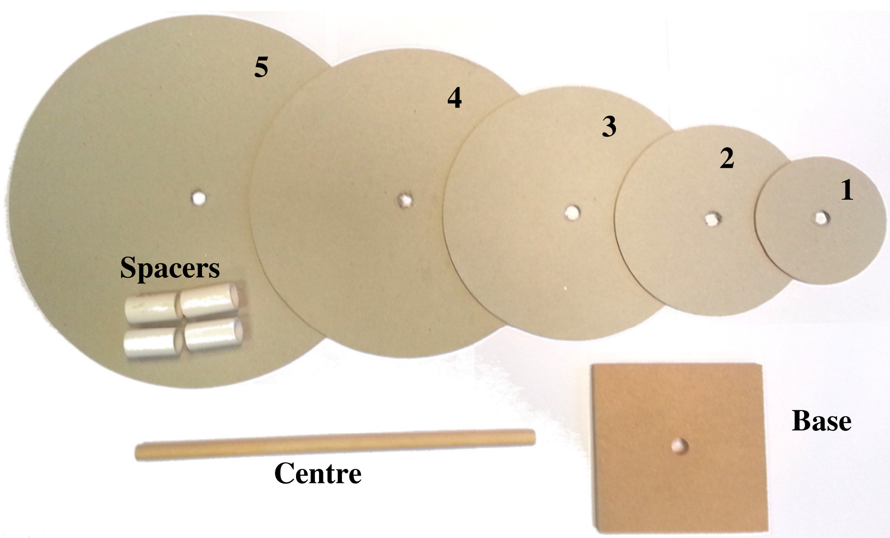

Figure 1: Materials provided to students

Data Analysis

The analysis of the data took place over two stages. Initial analysis was undertaken on all models submitted during round one of the study. This stage involved coding the data submitted into clearly defined stages. In total 19 various heading were found to have been used by students in the sample. In order to manage the data most effectively student defined headings were grouped into the five stages of design as outlined in table 1 below.

Table 1: Categorised heading given by the student sample

	Category	Categorised Headings
1	Analysis of design task	Brief, Brief Analysis
2	Research and Investigation	Research and Investigation
3	Design Evolution	Design Focus, Initial Design Ideas, Plans, Sketches, Modelling, Testing, Consider Materials, Chosen Design, Plan of Work, Working Drawings,
4	Realisation	Manufacture, Assembly
5	Evaluation	Evaluation, Conclusion

Where a student used two or more headings in one category an average value was calculated for the importance which that student placed on the category overall.

Phase two involved the analysis of the post design task models. As headings were provided during this task, analysis of the data was required to quantify the value placed on each stage of the design process by the students.

Results:

The following section presents the findings from the analysis of data outlined above. The results investigate the conceptual framework presented by the students and quantify the level of variance in students' perceptions towards the stages of the design process after their engagement with a semi-open design task. Two-dimensional samples of student work are outlined in figure 2 below. As in the student models, each stage is clearly labelled. It is through analysing such examples that the following results were calculated.

Analysis of the students' models through the pre-test indicates students' reliance on traditional structured models of designing. The order in which the design stages were presented resembles traditional reporting models (linear and cyclical). Reliance on various stages and the importance placed on these stages was indicative of the reporting mechanisms which students would have been accustomed to during post-primary education. This may indicate a level of conditioning towards a structured reporting process during post-primary education.

Comparison of Students pre and post models of the design process

The following section provides comparison of a selection of students (n.3) work both pre and post (figure 2). The models are presented in 2D for ease of interpretation. From the examples it can be seen that students' perceptions changed after their engagement with the design task. Due to the idiosyncratic nature of students and the nature of the design process variance across the results presented is comprehensible. Examples of this can be seen in the conceptual frameworks presented below. Student 1's perception of the stages of design became much more balanced in the post task model, with the student placing emphasis on all stages of design and a more equal importance placed on each stage. Comparatively, student 12 placed less emphasis on some stages of the design task.

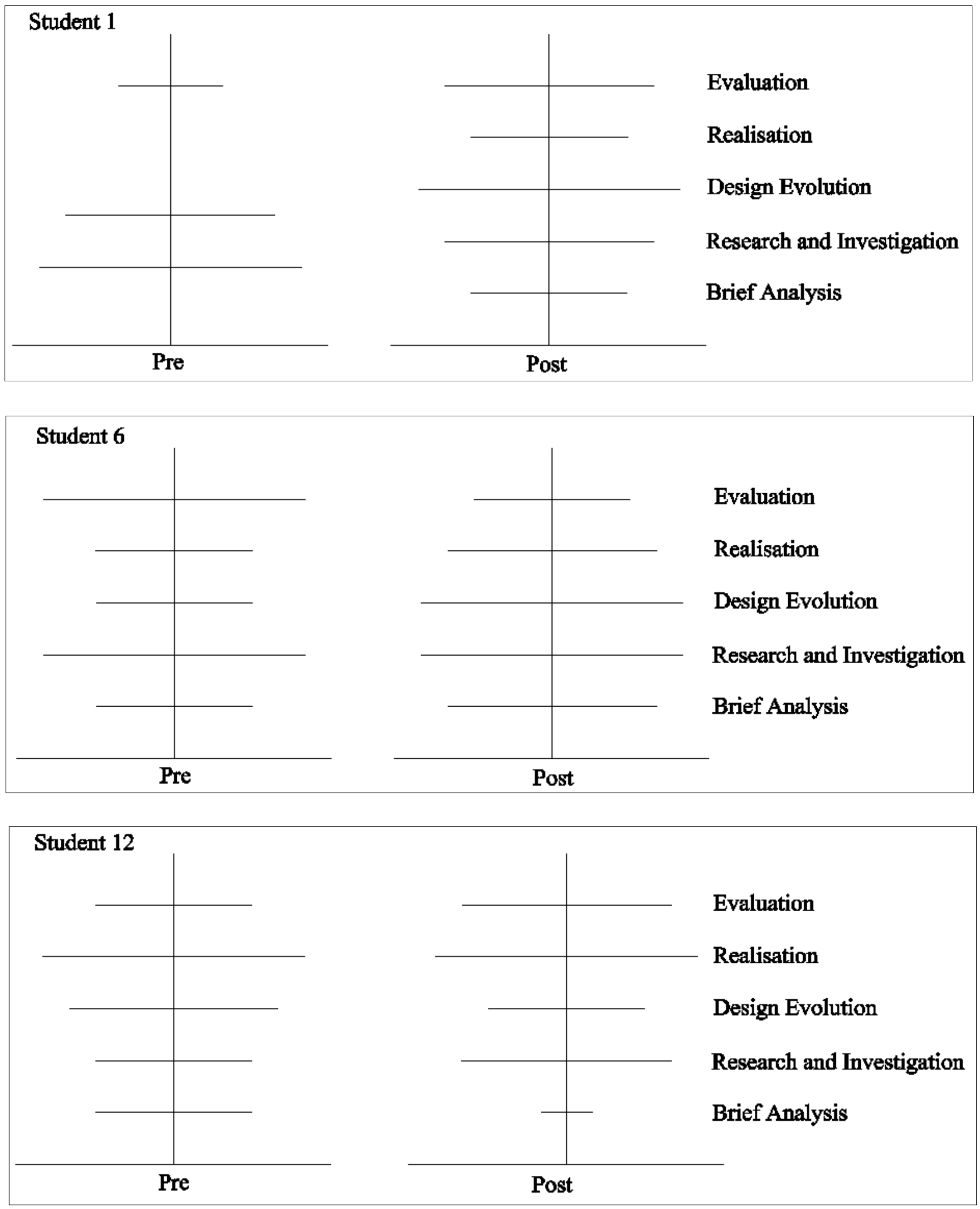

Figure 2: Samples of students' pre and post models

Variance in students' perception of the design process post task

The results presented in figures 3, 4 and 5 indicate the shift in students' perception in relation to the importance they placed on each stage of the design process. Positive results indicate an increased perception of the importance of a particular stage in respect to their individual learning experience. Equally, negative results indicate that following students' experience of engaging in a student centred design task, the importance which they now place on that stage has decreased. It is however important to note, that a negative shift does not indicate that the student deemed the stage unimportant, it indicates that in this specific design task the stage was not as important as they had initially interpreted it to be. A zero result is indicative of no movement in the importance placed on that stage of design by the student.

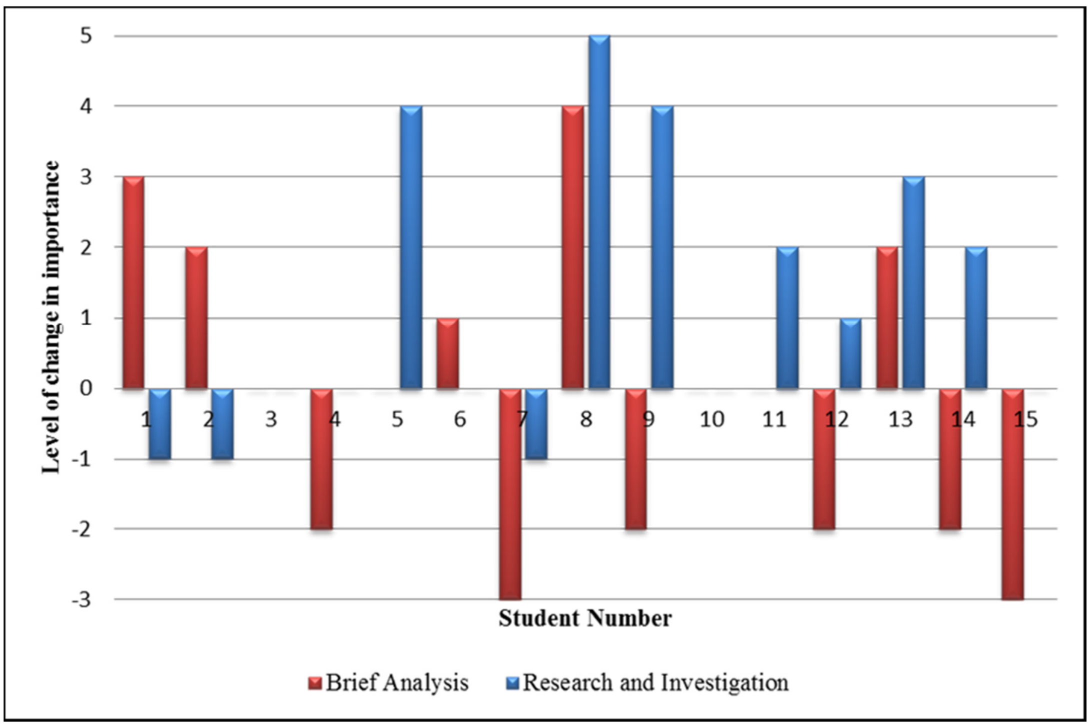

Figure 3: Variance in perception of the Brief Analysis and Research and Investigation stages

The results indicate that the experience of learning through the design based task impacted on the majority of students understanding of the design process. The act of reflecting on the task completed allowed students to challenge their preconceived understanding of learning through design and on their view of the process of design. Taking for example realisation (figure 4) all students examined either increased the importance place on this stage or deemed their initial understanding correct. These individual differences indicate towards the personal nature of learning through design activities and highlight the need for teachers to facilitate and support the individual nature of each student in their class.

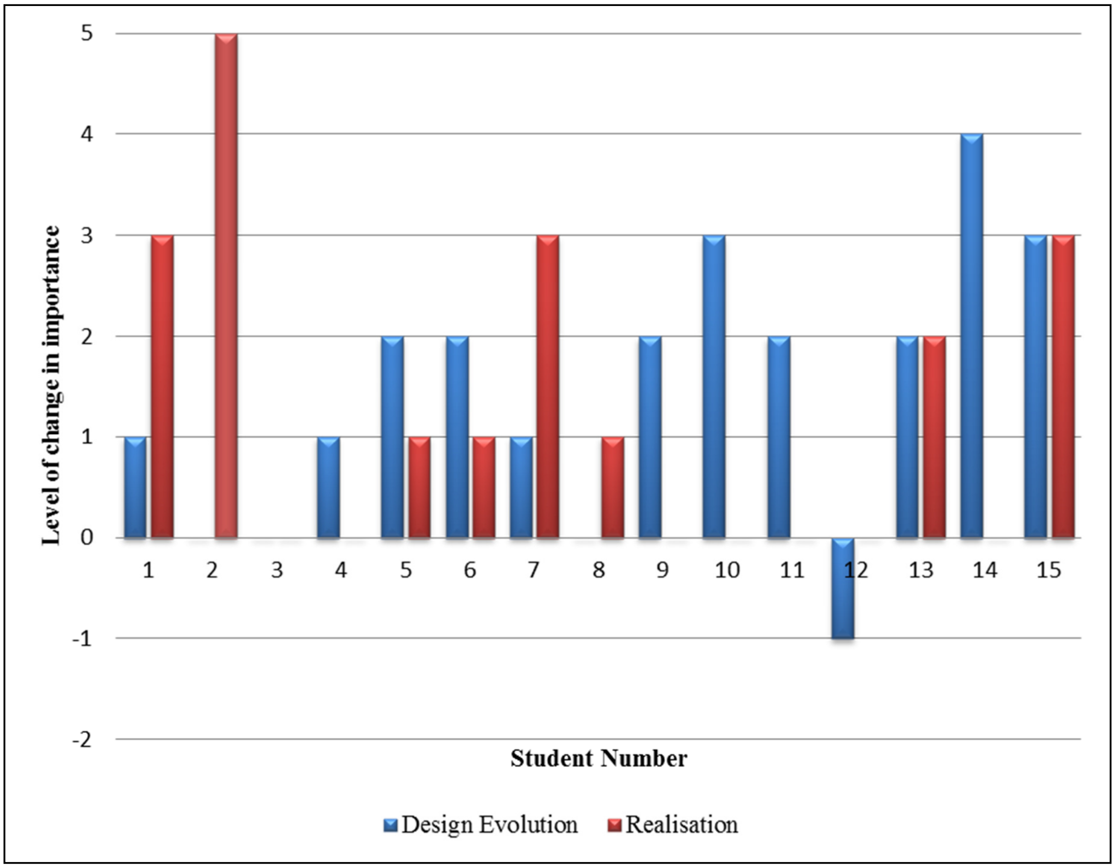

Figure 4: Variance in perception of the Design Evolution and Realisation stages

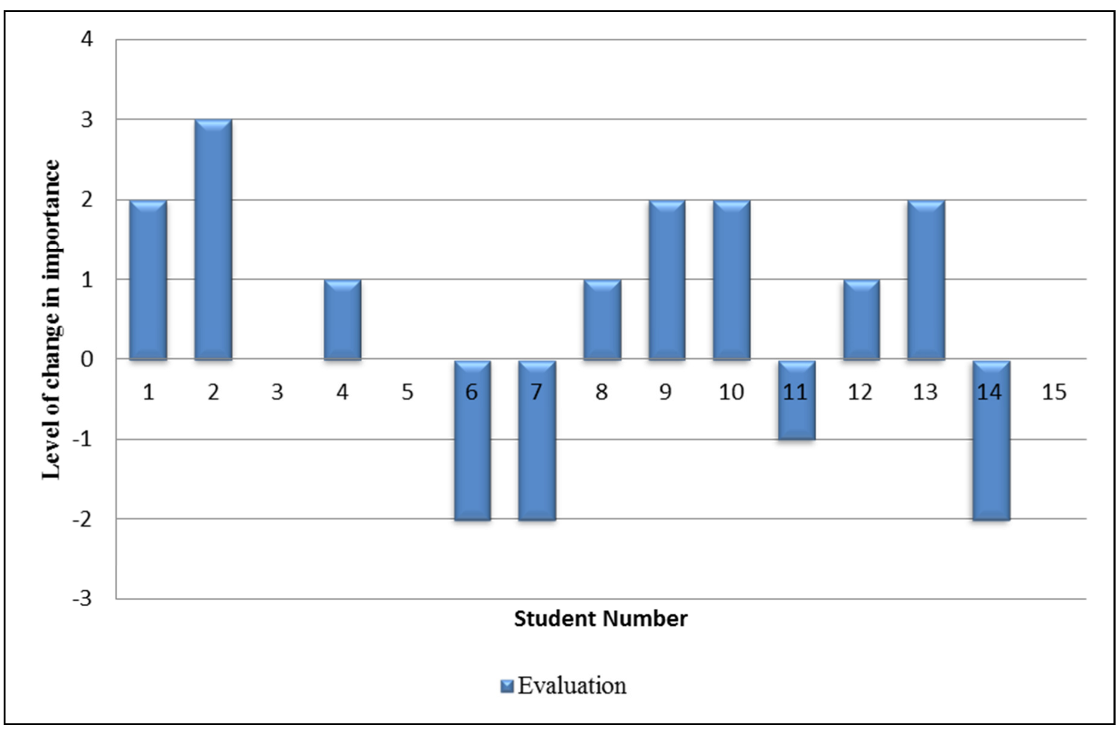

Figure 5: Variance in perception of the Evaluation stage

Interestingly, from the sample selected only one student, student 3, placed the same significance on all stages of the design process in both rounds of the study. In order to fully understand why this is the case additional investigation will need to be carried out where students are asked to qualify the decisions they made. Unfortunately this is beyond the scope of this research.

Discussion

As discussed by McLaren, the act of designerly thinking requires the assimilation of a range of cognitive processes to explore problems, situations, scenarios and it helps raise the questions and ignite the sparks of curiosity[20]. The act of engaging students in design through technology education provides students with a medium through which they can engage with a task which may not have a specific right or wrong outcome[21]. The role of design based technology education is to provide students with a range of transferable skills, values and knowledge which will be appropriate in solving problems[1].

This exploratory study aimed to investigate the importance which initial teacher students in design and technology placed on the design process in their learning. The idiosyncratic nature of the design process was explored through a reflective process which allowed students to develop an epistemological understanding of the role of the design process in their learning. The activity which students were engaged in allowed students take ownership of the learning process through a student-centred design task. The reporting mechanisms adopted throughout the design task allowed students to portray their understanding and learning in an open non-criterion referenced manner. This allowed for students diversity in approach and facilitated the development of individual students' epistemological understanding of learning through design.

The results presented allow us to analyse the stages of design which students deem appropriate to incorporate when designing while giving an insight into their emerging epistemological understanding of what learning through designing involves. By allowing students the freedom in the pre task analysis to provide the stages we can see a convergence on the traditional design process (cyclical) which are adopted in post-primary education in _______. This indicates students' reliance upon and indoctrination into the use of a structured design and reporting process.

By challenging through the design task outlined previously and encouraging students to develop their own understanding of the value of learning through design, a shift occurred in the value they placed on aspects of their learning. Through this study and the module as a whole students' were challenged "to explore and establish what is of value in their subject domain"[5].

As pre-service STEM educators their role will be to scaffold their pupils learning through a medium which will challenge them to be creative, innovative and to become effective problem solvers. They will be required to cater for a diverse group of learners, developing a broad skills and knowledge base. As has been shown through this research, learning through design is a dynamic process, where individual students engage with the process in their own way. As a result students should be allowed the freedom to express their learning through a medium which best suits their needs, and which presents the process of design through the students own interpretation of that process.

Conclusion

The results presented provide an insight into the students' interpretation of the design process and of the stages of design. Through students engagement in a task which allowed them the freedom to develop their own understanding of learning through design students' appreciation for the stages of design changed. It allowed students to construct their own understanding of what it means to learn through design and how diverse the process is. By sticking rigidly to a predetermined set of criteria stifles students' ability to create their own understanding of what is important. The iterative, dynamic nature of design process presented would indicate a need to allow students to take ownership of their learning and to engage with learning through design to suit their need. Education in this way places students at the centre of the learning process where teachers relinquish some control of the learning environment and place the responsibility on the student.

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