Graphics within Initial Technology Teacher Education: A Snapshot of Ireland and USA

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Graphics within Initial Technology Teacher Education: An International Snapshot

Abstract

Graphical capability is considered to be of fundamental importance across multiple disciplines. It involves the ability to mentally orientate and manipulate geometry, interpret graphical information and communicate visual thinking. Exploring and learning through the medium of graphics begins in early childhood and continues throughout adult life. The role of the education system in developing and nurturing graphical skills is sometimes understated. This paper considers the treatment of engineering design graphics within Initial Technology Teacher Education (ITTE) at the University of Limerick (Ireland) and North Carolina State University (USA). An in-depth review of the nature and purpose of graphics between both institutions is presented. A number of pertinent questions relating to the definition of being graphically capable and curriculum planning are presented. This paper will be of particular interest to academics who teach Engineering Design Graphics, high school teachers and engineers.

Introduction

"Graphics" are the representation of visual images with the purpose of communicating some information. Representations differ vastly in their purpose, mode of creation and in their level of abstraction [1]. They can be in the mind (internal) or they can be physically perceivable (external). Internal representations are private in nature and stimulate internal dialogue and reasoning about one's geometric problem solving and design thinking. On the other hand, external representations are public in nature and they form the basis for scaffolding internal dialogue and communicating graphical concepts [2]. Externalizations compensate for the limitations of inner representation and are the synthesis of graphical symbols. They can be elaborate, precise, detailed descriptions of a design entity, whereas others can be abstract in nature, varying in consistency, lacking scale and appear hurried. External representations take various forms which can include drawings, diagrams, charts, photographs, CAD models and sequential cartoons.

The externalization of images is a complex process which starts in early childhood. Exploring and learning through the medium of graphics is a fundamental part of a child's early education. The first explorations which involve the use of a crayon or pencil to make marks on paper are considered important catalysts in learning to draw. During early schooling drawing promotes play and discovery while bridging imagination and reasoning [3]. In progressing from elementary school to high school level, graphics are used in many applied contexts. These include the communication and interpretation of data through graphs and charts, the graphical reasoning of mathematical and geometric problems through freehand sketching, and the communication of design ideas using digital software.

Across the globe, curriculum policy and planning largely focuses on the development and promotion of numeracy, literacy and articulacy skills [4]. However, research has identified the importance of graphicacy across the education system in developing well-balanced human citizens [5, 6]. This paper discusses the purpose and role of graphical education within the high school system with a particular focus within Initial Technology Teacher Education (ITTE). The development of graphically capable teachers within two four year undergraduate degree programs is discussed in terms of underpinning philosophies and curriculum planning.

Technology Education in Ireland

Vocational education in Ireland has traditionally had a lowly position in Irish high (secondary) schools [7]. This is as a result of a historic divide between the philosophies underpinning the education provided in high schools and that provided by Vocational Education Committees (VECs). Following the establishment of the Irish Free State in 1922 the first Department of Education was formed and formal provision of high school level education was introduced [8]. In June 1924, under the Intermediate Education Act [9], the Intermediate and Leaving Certificate state examinations were launched. These examinations and their resulting qualifications were offered almost exclusively to students who attended private high schools [10]. By contrast vocational education differed in terms of its origin and

provision. Vocational Education Committees were established under the Vocational Education Act of 1930 [11] and were responsible for developing the infrastructure required to support vocational education and technical training in Ireland. However, at that time, these technical schools were not permitted to present students for state examinations. Students of technical schools were required to sit the Day Vocational Certificate Examination, commonly, known as the Group Certificate examination which was introduced in 1947 [8, 12]. This resulted in a clear academic/vocational divide in the Irish Education system as highlighted by Raftery and Hout [13, p.42];

> Those who complete their primary education follow one of three channels. Some terminate at the end of primary school, some enter an academic program in a secondary school, and the remainder receive specialized technical training and general course work at a vocational school.

Vocational and technical education also suffered from a lack of clarity as to what it involved and what pedagogical methodologies and strategies should have been employed to promote student learning. At the time there was a belief that the required skills could be best learned through formal apprenticeship and informal experience in the work place [8, 14, 15]. This divide in the role and function of high schools and technical schools remained, from a policy perspective and in practice, until 1966 when for the first time students from VEC schools were allowed to present for state examinations [8]. The following year saw the introduction of Donagh O'Malley's Free Education Act [9] which resulted in greater access to education and a significant increase in student numbers at high school level. The changing role of technical schools, coupled with free education dramatically changed the face of Irish high school level education. This broadening of the focus of vocational education schools resulted in less definitive educational outcomes which were traditionally governed by the type of school attended. The need to create technology subjects that were comparable to the classical academic subjects challenged the nature of technical education in Ireland [15]. As a result technology subjects were redeveloped to reflect more academic constructs. This is evident in the introduction of senior cycle Technical Drawing as a state examinable subject in 1969. This syllabus attempted to make the subject more academic and as a result concepts and topics were deliberately addressed in more abstract terms in an effort to distance itself from the applied, vocational nature of its origins [16]. However, recent years have seen a shift in focus for technology education, and in particular graphical education, within the Irish high school level system. Design and Communication Graphics (DCG) was introduced in September 2007 and replaced the Technical Drawing syllabus which had not been revised since 1984. This new DCG syllabus reflected a design driven philosophy of technology education that endeavours to form part of the holistic education of all students. As discussed in the syllabus it is envisaged that the "design theme, which permeates the course, will empower the students to communicate their design ideas and solutions with accuracy, flair and confidence" [17].

Philosophy of Graphical Education within Initial Technology Teacher Education at University of Limerick

The University of Limerick (UL) is the sole provider of high school Technology teachers in Ireland. The University offers a four year undergraduate training program which qualifies students to teach a suite of high school Technology subjects which includes Graphics, Metalwork, Woodwork, Engineering and Construction Studies. Recently, the Technology teacher education program at UL was reviewed and re-conceptualized in order to meet the requirements of the national teaching council.

The philosophy of the Initial Technology Teacher Education program at UL is to provide students with a broad learning experience where they develop an in-depth understanding and appreciation of the principles of their subject discipline and pedagogy, refine and develop cognitive and psychomotor skills, while integrating this with the study of educational philosophy.

Treatment of Graphics within ITTE at University of Limerick

The focus of the re-conceptualization of graphics within the four year ITTE program was informed by findings from contemporary research and several meetings between experts in the area of technology education at UL. Three broad, fundamental competencies were identified to become an effective teacher of graphics at high school level (Figure 1).

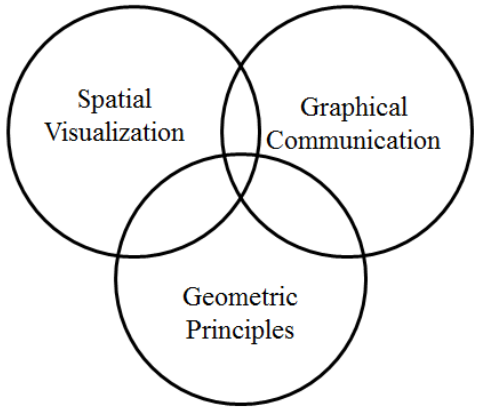

Figure 1 – Fundamental Graphical Competencies within ITTE

It is important that teachers have a clear understanding of geometric principles and in particular the fundamentals of plane and descriptive geometry. Well-developed spatial visualization skills are critical in order to effectively manipulate and synthesize these principles while graphically problem solving. Finally, the ability to graphically communicate through various mediums such as freehand sketching, CAD and model making is important in order to support the internalization and externalization of visual thinking.

In order to meet the challenges of developing teachers who are graphically capable, a macrostructure of progression was developed (Figure 2). The philosophy of building, manipulating and synthesizing is integrated throughout the program. The initial focus is to develop students' spatial visualization and graphical communication skills. Using these skills, the students begin to manipulate and synthesize their understanding of geometric principles through appropriate tasks. An integral part of the program is to expose students to the contemporary research related to graphics and technology education. Areas of study include cognitive development underpinning graphical capability, assessment within graphics education and subject specific pedagogy. Another critical aspect of the macrostructure and philosophy of the program is the increase in independent learning time for students as the four years progress.

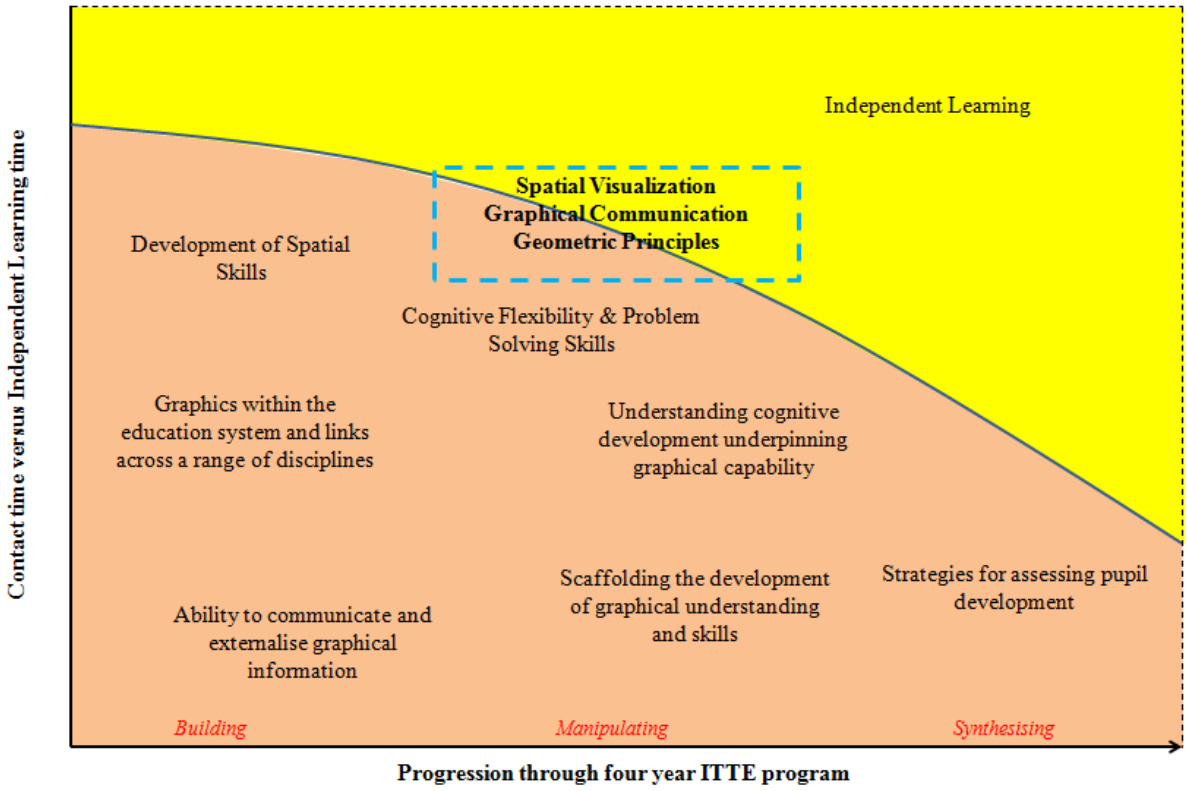

Figure 2 – Macrostructure of progression within graphics

General focus within each semester

The four year ITTE program at UL consists of eight semesters in total. Students experience teaching practice over a number of weeks in semesters four and seven. The following is a brief outline of the focus of each graphics module within the semesters. It should be noted that each module is required and students do not take any elective modules.

Table 1 – Breakdown of key learning outcomes at UL

Year / Semester	Key Learning Outcomes
Year 1 / Autumn Semester	• Development of spatial visualization skills through specially designed activities focusing on the physical and mental manipulation of geometry. • Explore, interpret and develop a broad range of graphical data. • Develop perception based fundamental freehand drawing skills with specific focus on scale, proportion and relationships. • Develop graphical libraries of geometric information in long term memory. • Explore and communicate geometries through a variety of projection systems including orthogonal projection and perspective with concurrent analysis of advantages and limitations of each method. • Introduction to contemporary research providing an insight into the theoretical underpinnings associated with spatial visualization, cognitive architecture and freehand sketching.
Year 1 / Spring Semester	• Analysis of plane geometry principles and associated mathematical underpinnings. • With particular reference to Euclid's Elements of Geometry, a grounded understanding of the principles associated with the construction of plane figures is developed. • Continue building spatial visualization and freehand sketching skills to support both internal dialogue and external communication of geometry. • CAD and other digital software are explored as media to aid in the dynamic communication of plane geometry principles. • Develop an appreciation for and apply drawing conventions and standards in communicating measured graphical information. • Further development of freehand drawing skills - retrieval and communication of imagery through activities focusing on the visuo-spatial sketchpad of short-term memory.
Year 2 / Autumn Semester	• Analysis of the philosophy and structure of lower level, high school Graphics curriculum. • Explore the application of plane geometry principles in a descriptive and applied context. Freehand and measured drawings, physical modeling and 3D parametric CAD are utilized in exploring various projection systems for the communication of descriptive geometry principles. • Analyze various projection systems and be able to make informed decisions when selecting a suitable system for communicating graphical information. • Utilize freehand sketching skills to support internal dialogue while graphically problem solving. • Explore different non-graphical methods communicating geometric information to different audiences across different disciplines.
Year 3 / Autumn Semester	• Analyze the upper high school level Graphics curriculum in terms of its philosophy and structure in addition to its progression from lower level high school Graphics. • Further develop freehand sketching skills through appropriate activities which facilitate the retrieval, manipulation and synthesis of geometric libraries - generating creative concepts and communicating these through ideation sketches. • Examine contemporary research relating to graphical communication and the role of human memory systems in supporting internal dialogue. • Analyze the different functions of design and explore the various stages using sketching, CAD modeling and physical modeling (including CNC). • Discriminate between different media and select as appropriate. • Further explore descriptive geometry problems with a specific focus on geometry in contemporary design.
Year 3 / Spring Semester	• Synthesize and challenge students understanding of geometric principles through applied geometry activities. • Demonstrate cognitive flexibility in solving a range of graphical problems in which various graphical principles are synthesized. • Explore strategies for stimulating pupil interest, discriminating between mixed ability learners and supporting the development of different abilities in a whole class situation. Consider graphical principles through various media in a pedagogical context and in particular focusing on the scaffolding of pupil understanding. • Discuss the design of appropriate tasks to capture graphical capability and understanding. • Synthesize experiences and knowledge of graphical principles together with a grounded understanding of cognition in designing suitable assessment strategies.
Year 4 / Spring Semester	• Students undertake an individually driven capstone project • The focus of this project centers around innovations that will contribute towards the development of graphical capability and the promotion of graphical subjects in high schools

****** Teaching practice placement takes place in Year 2 - Spring Semester & Year 4 - Autumn Semester

Although the main focus of this paper is on the philosophy and nature of graphics at University of Limerick, it is also important to consider the treatment of graphics through an international perspective. There are several reasons for this including the fact that graphics is a global language and it could stimulate discussion at the conference in relation to curriculum influences and planning. The next section of this paper considers the role of graphics within an Initial Technology Teacher Education program at North Carolina State University (NCSU).

Philosophy of the Technology, Engineering & Design Education Program at North Carolina State University

The faculty of the Technology, Engineering and Design Education Program at NCSU believes that they are preparing the innovators of tomorrow. In order to do this, students must develop a broad range of knowledge and skills that help them be creative and productive. The goal is to prepare teachers and leaders for schools, industry, business or community who are knowledgeable, skillful, and innovative in their technology related professions. These individuals should be change agents to help advance their fields.

The Role of Graphics Education and the Development of Graphical Competencies

Since one of the goals of the NCSU program is to prepare innovators, many of the classroom and laboratory activities are based on engineering design processes where students create modeling artifacts to help develop solutions to problems. These artifacts include conceptual models, graphical models, mathematical models, and working models [18]. Graphics tend to be a large part of creating these models, so students need to develop competencies in a variety of graphical areas in order that they may apply them as cognitive tools (e.g., visualization sketching and concept mapping), design tools (e.g., design sketching, 3D modeling, electronic publishing, and design analysis), or documentation tools (e.g., rendering, animation, and engineering drawings) (Figure 3).

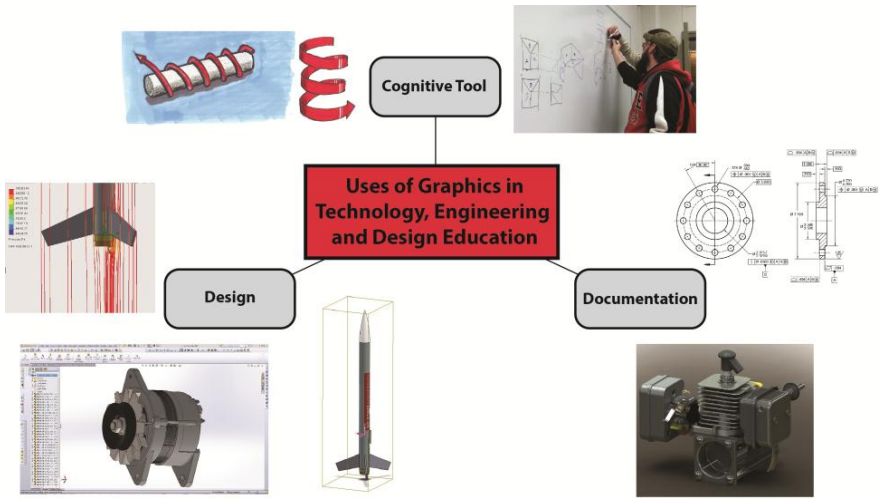

Figure 3 - The Use of Graphics in Technology, Engineering & Design Education

To develop these competencies, students have required courses in engineering graphics, 3D constraint-based modeling, architectural graphics, and imaging technologies (Table 2). They also have electives available in descriptive geometry, visual thinking, and advanced computer aided design. These electives, along with other technical electives in the program, allow students to specialize in either engineering design graphics or electronic imaging technologies.

Table 2 - Competencies in Graphics Courses at NC State University

Course	Competencies	Project
Foundations of Graphics *Required*	Basic multi-view and pictorial sketching. Engineering graphics standards and conventional practices. Introduction to SolidWorks – parts, assemblies, and drawings.	Reverse engineer a design with 5-7 parts. Document size and shape of parts through sketches. Create 3D models and a rendered assembly. Generate detail drawings.
Applied CAD & Geometric Controls *Required*	Working drawings. Threads & fasteners. Geometric dimensioning & tolerancing. Constraint-based CAD concepts: design tables and configurations, programming, sweeps, lofts, assembly drawings.	Develop a complete set of working drawings of a 10-25 item assembly. Model all parts, create detail drawings of all non-standard parts, and create an assembly drawing of the final design.
Architectural Graphic Communications *Required*	Residential and commercial architecture standards and conventional practices. Floor plans, elevations, details, and plot plans. Introduction to AutoCAD.	Design a modest home. Include all required drawings necessary to manufacturing the dwelling. Build a prototype of the home.
Desktop Publishing and Imaging Technologies *Required*	Design principles in desktop publishing. Typography. Digital photography basics. Creating print-ready documents using Adobe InDesign, Illustrator, and Photoshop.	Work with a real client and develop a usable product for their company. Projects may include brochures, newsletters, menus, etc. All graphics must be original.
3D Spatial Relations *Elective*	Lines & Planes – Lines: true length, true slope, bearing. Planes: true slope, true size & shape.	Given a contour map of a piece of land, develop a road a specific elevation. Create a new drawing

	Shortest connectors. Angle between line and plane. Intersections between surfaces. Developments – radial line, parallel line Civil engineering applications	with the road defining the cut and fill at specified grades. Create a virtual model and a physical model of your solution.
Visual Thinking *Elective*	Sketching – perspectives, figure drawing, etc. Seeing, imaging and drawing. Alternative strategies to foster productive creative thinking.	Create a Visual Metaphor (or Prototype) which will be presented and group evaluated in class.
Advanced CAD *Elective*	History of constraint-based CAD. Anatomy of constraint-based CAD. Downstream uses of 3D models. Advanced tools in SolidWorks: Surface modeling, sheet metal, equations, analysis (FEA, CFD, etc.).	Team project: Reverse engineer a complex design; divide design into meaningful subassemblies; reverse engineer individual parts; model parts; assemble parts; create documentation drawings and rendered images; present to class.

Strengths of the Graphics Element at NC State

The strength of the graphics element in the program at NC State is engineering design graphics and constraint-based computer-aided design. Since the program and faculty have a tradition of offering service courses in graphics to engineering and the rest of campus, students in the Technology, Engineering & Design Education program get a chance to interact with students from a variety of majors – especially engineering. Although they do not graduate as engineers or product designers, students in the program are learning how to think as engineers and designers. They learn to use powerful engineering design tools to create virtual prototypes and conduct complicated analyses on their designs.

Discussion

The purpose of this section is to raise some questions in relation to graphics within ITTE from an international perspective.

First of all it is important to consider the philosophy and nature of graphics education within ITTE at UL and NC State. Although great strides have been made in UL in modernizing the focus of high school graphics subjects, there still remains a profound focus on plane and descriptive geometry. It is considered important that in order to be graphically capable, students should have a good understanding of these principles. However, at NC State the study of descriptive geometry through 3D Spatial Relations is an elective module of study. This observation raises several questions… Is it important for students to study plane and descriptive geometry? Do students need to know the underpinning mathematical theorems relating to certain geometric principles if CAD systems can already do this?

It is notable that students at NC State have required modules and electives while students at UL can only take required modules and do not have the opportunity to take electives. How much of a focus is there on the national curriculum? What are the merits of having required

modules and electives? How can you ensure that teachers will be graphically capable when graduating from the program if they must choose between electives? Is it possible to develop innovative teachers who can think independently when they don't have the opportunity to take electives?

The treatment of graphical communication between UL and NC State is interesting. Proficiency in freehand sketching and CAD applications is seen to be critical from a pedagogical and visual communication standpoint. It is interesting that freehand sketching skills are developed as part of an elective module in Visual Thinking at NC State whereas freehand sketching is integral to all modules of study at UL. In order to be graphically capable, is it necessary to have proficiency in all media? If a student has a keen interest in ICT (Information and Communications Technology) and well developed CAD skills, do they need to have the same level of expertise in freehand sketching?

The primary focus of the teacher education program at UL is on developing high school technology teachers. The focus of the teacher education program at NC State is on developing teachers and leaders for schools, industry, business or community. What are the merits of streamlining the development of teachers solely for high schools? Is there any risk of diluting the teacher as a professional if the focus reaches further than the high school system? Is it disadvantageous to solely develop students as high school teachers? What if they would like to broaden their career outside of the high school system during life? Is the four year program appropriate? Should teachers have a general degree and take a teaching qualification at post graduate level afterwards?

Finally, it is important to revisit the topic of graphicacy and what it means to be graphically capable. There is little doubt that being graphically capable has significant importance across multiple disciplines and that there are many cognitive and psychomotor benefits. However, it is apparent that there are some underlying questions which are of interest to people within engineering design graphics. What does it mean to be graphically capable? What are the core competencies of a graphically capable human citizen? How can these competencies be developed?

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