Chapter 9
Promoting Design Thinking Through Knowledge Maps: A Case Study in Computer Games Design and Development Education

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Abstract Modern computing is pervaded by human-centric technologies which potentiate people's capabilities to address complex problems and needs in contextualised and meaningful ways. Creating such technologies requires thinking approaches that overcome the limitations of traditional paradigms that focus on specific aspects of human-computer interaction in well-defined problem contexts. Design thinking is an ill-defined problem-solving strategy which addresses this need through a systematic and iterative process that integrates exploration, ideation and testing of possible solutions based on the participation of stakeholders, and the investigation and accommodation of their often-conflicting needs. Developing design thinking in students is key to face the challenges of an ever-changing and increasingly complex world, and it is therefore crucial to have approaches and tools that can support educational endeavours aimed at this. In this chapter we describe the use of knowledge maps to promote design thinking for game design and development students. Knowledge maps are a variant of hierarchical concept maps created by domain experts to support learners' knowledge construction processes. Game design knowledge maps were conceived to integrate and structure multidisciplinary knowledge regarding game systems, players, player engagement principles, and design and testing processes. Their structure was planned so that students could explore imparted knowledge iteratively and incrementally, driven by a human-centric focus. The evidence collected from students so far indicates that knowledge maps integrate large amounts of information in an easily accessible structure which fosters students' design thinking processes. The maps seem to support students in connecting themes and ideas, and guide them through

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the whole design thinking process. This suggests that properly structured imparted knowledge can be effective in helping students to learn "how" to think, not just "what" to think.

Keywords Design thinking · Concept maps · Game design · Education
Problem solving

9.1 Introduction: The Need for Human-Centred Design Thinking in Computer Science Education

Nowadays computing devices permeate and shape many aspects of our lives. They influence the way we work, socialize, learn, play, and engage in the many other types of activities that define our daily living, and through which our identities are defined. Nowadays more than ever before computational devices and computer programs are conceived because of people and for people, to address their complex needs in complex contexts.

The defining power of computational technologies is due to how these are designed to mediate human activity, putting abstract technological features at the service of meaningful human needs and wishes (Jaimes et al. 2007). Accordingly, modern perspectives on computing emphasise the importance for Computer Science—henceforth referred to as CS—to fully embrace human-centric approaches (e.g. Taylor 2000; Jaimes et al. 2007; Grudin 2012). This implies that CS should be regarded as a scientific endeavour aimed at studying in equal measure what computational artefacts "can do" in abstract, how they can mediate human life, and how they can be designed and implemented for this purpose. By extension, CS education should aim at enabling students to design, develop and evaluate computational artefacts embracing human-centric perspectives.

User-centredness is not new to CS. In fact, focus on computer-human interaction has been key to drive the evolution of CS and CS education since the 1970s (Grudin 2012). "Human-centrism", however, entails more than attention to the process of interaction between humans and computers. Adopting a human-centric approach requires focussing on the whole human experience, rather than purely on abstract features of technological artefacts (Taylor 2000; Giacomin 2014). Computational technologies should be treated as mediators of contextualised and purposeful human activity, focussing on how they can augment the users' capabilities to interact with their environments in desirable ways, and how technological potentialities are perceived by the "user" (cf. Bannon 1991; Buchanan 1992; Giacomin 2014). For this, the user, the technological artefacts, and the context and purpose of technology uses should be treated in an integrative way, accounting for the possible effects that technology may have on users and their environments (Bannon 1991; Taylor 2000; Giacomin 2014). This requires a systematic way of thinking, suitable to tackle ill-defined problems through iterative processes of creation of solutions driven by user-centred evaluations: human-centric design thinking. By extension, promoting design thinking should be a key priority in education focussed on human-centred creation of technology (cf. Cross 1982; Oxman 1999; Dym et al. 2005; Dunne and Martin 2006; Fabricatore and López 2015, in press).

What are the characteristics of design thinking? What can be done to promote its development through formal education? To address these questions, in this book chapter we will first discuss the distinctive properties that characterize design thinking as a systematic reasoning strategy. Then, drawing from key research on design thinking education we will outline key strategies to foster design thinking through formal education. Accordingly, we will analyse a key challenge that frequently hampers design thinking education: the provision of knowledge to students. We will then introduce our response to this challenge: design knowledge maps. These are a variant of concept maps that we have created in order to provide structured knowledge suitable to scaffold the development of design thinking in the domain of computer game design and development education. Through a case study we will outline the structure of a game design knowledge map, discussing its underpinning rationale and exemplifying its implementation. We will then report preliminary impacts investigated so far. We will conclude this chapter with some reflections on the need to increase efforts to promote design thinking within CS education, and the possibility to use design thinking knowledge maps outside the domain of game design and development.

9.2 The Engine of Human-Centredness: Design Thinking

Design thinking can be regarded as an applied reasoning strategy that integrates investigation, strategic planning, construction and testing of systems to address open-ended, ill-defined problems involving multiple interacting stakeholders (Buchanan 1992; Taylor 2000; Dorst 2011). The core purpose of design thinking is to formulate solutions aimed at generating impacts valuable for all the stakeholders involved in the problem situation (Buchanan 1992; Dunne and Martin 2006). Unlike well-defined problem-solving approaches, design thinking addresses problem situations in which there exist no optimal or definitive solution, and there is no possibility to gain full and stable knowledge of requirements and working principles underpinning problem scenarios. Stakeholders may be (and often are) influenced by conflicting needs and constraints. These needs and constraints are likely mutable, not fully knowable nor predictable, as are the environmental conditions that define the contexts in which stakeholders exist and interact. Consequently, design thinking explores and models problem situations through different perspectives, ideating, implementing and testing alternative solutions based upon incomplete and uncertain information. This contrasts with well-defined problem-solving strategies that aim at formulating "optimal" and "definitive" solutions based on full and stable understanding of the problem situation. This distinguishes design thinking as an iterative problem-solving process which systematically integrates abductive, deductive and inductive reasoning

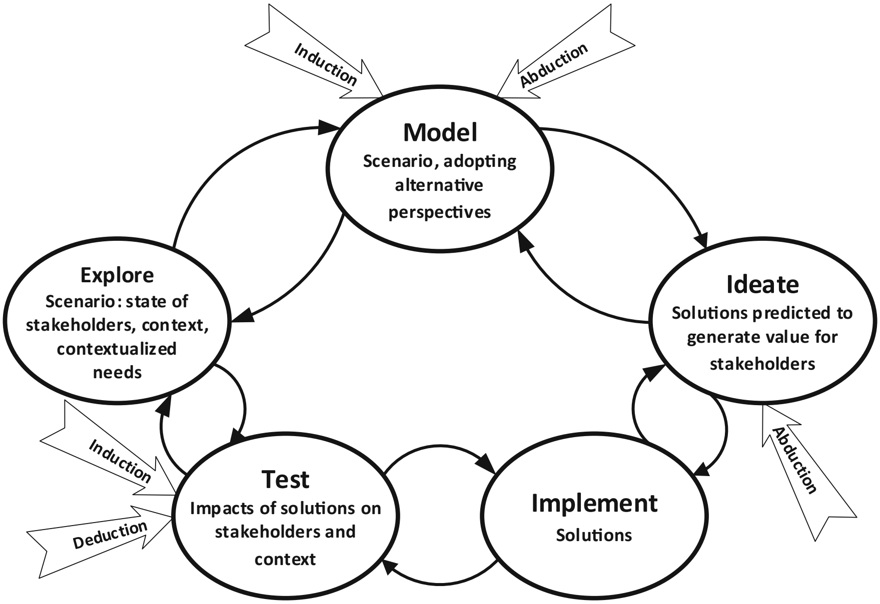

Fig. 9.1 The design thinking process

in a cycle of progressive approximation to an "acceptable", "good enough" solution (Fig. 9.1). The structure and rationale of the design thinking process, and its focus on stakeholders and their context characterize design thinking as a human-centric problem-solving approach suitable to tackle complex problem situations (Buchanan 1992). Furthermore, the way design thinking integrates generation of novel ideas with their practical implementation and testing makes of design thinking a process of innovation (Dunne and Martin 2006).

9.3 Design Thinking as a Systematic Problem-Solving Approach

As previously mentioned, a key and distinctive feature of design thinking is how it systematically integrates abduction, induction and deduction in problem-solving. A problem can be generally regarded as discrepancy between a current state of matters and a desirable goal state in a given situation. A problem situation can be viewed as a system of interacting elements. Accordingly, a problem is defined by information regarding: the type and state of elements involved in the system; the contextual conditions in which they interact; the working principles that regulate their interactions and state changes; and the desirable goal to attain.

When a problem situation is stable, it can be reliably investigated and defined through direct exploration, using deductive and inductive reasoning (Dorst 2011). First of all, stability implies that the state of system elements can be known through exploration of the problem situation at any point in time. Then, if the working principles are known, given a present state of the problem situation it is possible to apply deductive reasoning to predict future states: knowing "what" is involved in a situation and "how" it functions allows predicting "outcomes" of the functioning (Dorst 2011). If the working principles are not known, inductive reasoning can be applied to hypothesize them based on observation of patterns in system state changes: knowing "what" is involved in the situation and observing the "outcomes" of its functioning allows hypothesizing "why" it may have changed and, by extension, "how" it functions (Dorst 2011). These mechanics allow to apply a linear problem-solving approach to define how to modify a system in a desirable way. If current state, working principles and goal state are defined, abductive reasoning allows hypothesizing which aspect of the system should be modified so that the goal state will be attained: knowing "how" things work and knowing the desired outcome of their working allows defining "what" things should be modified to achieve such outcome (Dorst 2011). Deductive reasoning can then be used to confirm or refute hypotheses, through implementing the planned changes—i.e. the "solution"—and testing their effects against the predicted outcomes. For example, imagine that one wanted to improve the strength of tennis players' swings (goal state). To achieve this, knowing that the weight of a racket affects the strength of tennis strokes according to well-defined mathematical models (working principles) one might design a lighter racket, using for the very first time a revolutionary material: graphene (Already used for racquets!?! Too bad…).

In the case of open-ended problem scenarios, the situation may be significantly more complex, unstable and ill-defined. In these cases, the elements involved in the problem situation and the working principles that regulate them may be unknowable, changing and uncontrollable to some relevant degree. This requires using abductive reasoning for the iterative formulation and testing of parallel hypotheses on working principles and solutions, through a systematic process which is distinctive of design thinking (Fig. 9.1). Given a desirable value (goal) to attain, the designer frames the problem situation adopting alternative perspectives and formulating different and likely complex models (Buchanan 1992; Dorst 2011). Each model includes inductively inferred and abductively hypothesized working principles, and a thesis that associates these with the desired value to attain: "IF we look at the problem situation from this viewpoint, and adopt the working principle associated with that position, THEN we will create the value we are striving for" (Dorst 2011, p. 525). A model is then selected and, based on the hypothesized working principles, a solution to attain the desired value is abductively formulated and implemented. Deductive reasoning is then used to test the hypothesized solution and, by extension, the underpinning working principles. If the solution generates the predicted value, its validity and the underpinning working principles are inductively generalized (Dunne and Martin 2006). Otherwise, abductive hypotheses regarding solution and underpinning working principles may be reformulated and tested through a new iteration of the entire process, or the framing may be changed all entirely (Dunne and Martin 2006; Dorst 2011).

To exemplify the process, let us consider an oversimplified fictional case. Pretend that the value pursued was enhancing wellbeing in the context of rural jungle communities in Nowhereland. After exploring the problem situation one might hypothesize that people living in those communities enjoy socializing (working principle). Therefore, one might theorize that if socialization opportunities were enhanced, then wellbeing would increase (abductive thesis, relating hypothesised working principles and desired value). To complete the framing, one might have observed that most people have old mobile phones whose usage is limited to voice calls and SMS. At this point one might have sufficient information to hypothesize that a good solution could be an innovative product: JungleTxTClub®, the first ever SMS-based social networking platform interfaced with larger, non-SMS-based platforms (Already done?!? Oh no…) Assume that, embracing the "social networking framing" of the problem situation, one developed and tested this solution for a month, only to discover that the average use decreased drastically day after day. This apparent failure would then lead to reviewing the working hypotheses and the solution. Through this process, one might interview a sample of users, discovering that the idea of digital social networking is appreciated. However, users found typing on the mobile keyboard cumbersome. One might then infer inductively that there is a problem with the user interface, reviewing the solution accordingly, and initiating a new cycle of the design thinking process.

9.4 Design Thinking as Human-Centric, Social Process

Stakeholders are the fulcrum of the design thinking process (Buchanan 1992; Taylor 2000; Dunne and Martin 2006). Design thinking tackles scenarios which are "problematic" first and foremost because they involve stakeholders who have latent or manifest needs that require addressing. Stakeholders do not consider themselves mere "users" of products and services: they are human beings concerned with the quality of their lives, their activities, and the impacts that products and services can have on these (Giacomin 2014). This is why the primary focus of the design thinking process is not "the solution", but rather "the need in context" and "the value" to be generated to address contextualised needs. By extension, design thinking is not only concerned with the direct impacts of a "solution". Driven by social and ethical considerations, it accounts for broader implications that "solutions" may have on stakeholders and their contexts (Buchanan 1992; Taylor 2000).

Design thinking also acknowledges that stakeholders are diverse. Their perspectives and circumstances may be different. As a consequence, their needs may conflict. A given scenario will likely not represent the same "problem" for all stakeholders, and what could be perceived as a "solution" by some, might represent a "problem" for others (Buchanan 1992; Taylor 2000; Dorst 2011). It is in order to address diversity that design thinkers frame problem scenarios through different perspectives, exploring alternative frames in search of models that can accommodate as much as possible all the involved stakeholders.

Stakeholders' needs and circumstances may be mutable and not fully manifest: not everything may be knowable through observation, and what has been observed may change. To address this, design thinking integrates observation, dialogue and inquiry in order to involve stakeholders throughout the problem-solving process (Buchanan 1992; Dunne and Martin 2006). Background information on stakeholders is obviously a key starting point to frame the problem situation tackled. Observation serves to infer relevant behavioural patterns of the stakeholders, salient aspects of their circumstances, and impacts of implemented solutions. Inquiry and dialogue are used to gather information directly and intentionally provided by stakeholders, which closely represents their perceptions of the problem situation. Stakeholders are not just a source of information. Through dialogue stakeholders are involved in joint decision-making and evaluation processes, as in the case of the definition of the value to be attained, the selection of framing perspectives, and the evaluation of impacts attained (Buchanan 1992; Dunne and Martin 2006). This promotes the accommodation and integration of conflictive views in case of conflict.

9.5 Design Thinking as an Innovation Process

Design thinking cannot be fully outlined without highlighting its intimate connection with creativity and innovation. Exploring alternative perspectives and accommodating conflicting needs requires thinking outside existing and evident alternatives, creating and testing new options, and embracing constraints as challenges, rather than barriers and causes for compromise. This makes of creativity an intrinsic element of design thinking. The exploration of non-yet-existing possibilities is not purely conceptual. As possibilities are iteratively developed through cycles of design and testing, design thinking integrates conceptual analysis and practical synthesis in a dialectical process. Thus, design thinking fully mirrors what innovation is: a process of generation and implementation of novel and useful ideas in response to open-ended problems and opportunities (Fabricatore and López 2013). Design thinking as a whole IS a process of innovation.

In sum, design thinking can be regarded as a human-centric, systematic and creative process ideal to address meaningful human needs through the generation of innovative technological solutions. This is of paramount importance nowadays, when people need solutions to improve their lives in increasingly complex contexts, industries compete to generate innovative solutions, and formal education strives to equip students to tackle the challenges of our complex world (cf. Dunne and Martin 2006; Dym et al. 2005; Fabricatore and López 2015; Koh et al. 2015). How can design thinking be fostered within formal education?

9.6 Fostering Design Thinking Through Formal Education: Implications and Challenges

Since the 1990s there has been a growing interest in studying the cognitive aspects of design, and educational research on design thinking has developed accordingly (Cross 1982; Oxman 1999, 2004). It has been acknowledged that learning design thinking means enhancing real-world problem-solving capabilities (cf. Cross 1982; Oxman 1999; Dym et al. 2005; Dunne and Martin 2006). Researchers have consequently investigated strategies to promote the development of the thinking skills and attitudes involved in design thinking, and foster the conscious assimilation of the reasoning patterns underpinning the design thinking process (cf. Oxman 1999, 2004; Dym et al. 2005; Fabricatore and López 2014, in press). A significant consensus has been reached regarding key features that educational strategies should incorporate for these purposes. Drawing from our past research (Fabricatore and López 2014, in press) and echoing key trends in design thinking educational research (cf. Cross 1982; Oxman 1999, 2004; Dym et al. 2005; Dunne and Martin 2006; Koh et al. 2015), we suggest that these features can be summarised as follows:

i. Focus on project-based learning activities, aimed at addressing open-ended, ill-defined problems involving multiple interacting systems, and underpinned by multiple knowledge domains.
ii. Contextualization of problem situation mirroring real-wold scenarios, involving: diverse stakeholders; properties of contextual conditions and stakeholders which are neither fully knowable nor fully predictable; social as much as technological implications for the involved stakeholders.
iii. Iterative and incremental organisation of project work, integrating multiple cycles of design, implementation and evaluation of solutions.
iv. Promotion of students' collaboration and self-organisation of project work, involving: team-based project work motivated by the intrinsic complexity of the problem tackled; roles and responsibilities organised by students, based on iterative exploration of problem scenarios and provisional outcomes of project work.
v. Promotion of direct and indirect exploration of and interaction with key stakeholders involved in the problem scenarios tackled.
vi. Provision of adaptive pedagogical support, involving: upfront provision of explicit core knowledge, firstly useful to promote shared understandings, and later on freely accessible to learners as a scaffold; adaptive provision of explicit supplementary knowledge, ad hoc, depending on project progression and learner profile/learning style; enabling, non-prescriptive tutor feedback, promoting the adoption of alternative perspectives to frame problems, and the prediction and critical analysis of implications of possible solutions; mediation of team dynamics, to promote mutual understanding and self-organisation.
vii. Tailorization of project constraints to maximize their enabling value, ensuring that: project-specific constraints promote the exploration of alternative perspectives and the formulation of different solutions to the problem tackled; admin-

istrative constraints (e.g. academic policies and regulations, etc.) do not hinder students' self-organization and possibilities to embrace varied approaches to project work.

All the above features are underpinned by a pivotal element: the knowledge imparted to learners. Its contents and structure should reflect the comprehensive type of knowledge involved in design thinking, and support knowledge building processes similar to those carried out by expert designers (Cross 1982; Oxman 1999; Fabricatore and López in press).

Designers develop solutions through constructing knowledge regarding a problem situation which can be generally viewed as a system of interacting elements (cf. Cross 1982; Fabricatore and López in press). As they explore problem situations, designers observe, identify, classify and infer concepts and their connections, building meanings in order to hypothesize working principles that govern the problem system tackled, and ideate possibilities to influence it in desirable ways (cf. Buchanan 1992; Oxman 1999; Dorst 2011). This can be assimilated to a purposeful process of construction of knowledge based on meaning-making: meaningful learning (Novak 2010). The knowledge acquired and constructed through the design thinking process concerns the "what" of design, as much as the "how" and the "why" (cf. Cross 1982; Oxman 1999, 2004; Dym et al. 2005). This knowledge can be regarded as a system of concepts and propositions (Novak 2010). It may be factual, inductively inferred, abductively hypothesized, and deductively corroborated through the design thinking process. Regarding the "what", knowledge involved in design thinking relates to attributes and relationships of key elements of the problem system investigated—including stakeholders and other relevant contextual elements—and the solution being designed. Regarding the "how", knowledge regards techniques and tools useful to explore and modify the system being tackled, and strategies to organize and apply techniques and tools. The "why" concerns working principles regulating interactions between system components. This knowledge allows designers to reflect on the suitability of tools, techniques and strategies in relation to the effects that they might have on the systems tackled. It serves to predict or critically evaluate direct effects and broader implications of possible solution approaches.

The contents of the knowledge imparted to students should be integrative, comprehensive and multi-disciplinary, covering the "what", "how" and "why" of design (Cross 1982; Oxman 2004; Dym et al. 2005; Dunne and Martin 2006). For this, the structure of knowledge is as important as its contents (Oxman 1999, 2004; Novak and Cañas 2008). The knowledge imparted should be organised connecting information about the "what", "how" and "why" in scaffold structures which students can assimilate and use as a basis to build their own conceptual structures (Oxman 1999). The knowledge imparted should also be mainly explicit and objective, rather than subjectively defined and verbally conveyed by tutors (Oxman 2004). Non-explicit knowledge is only temporarily embodied in the words of the tutor, and is dependent on the tutor's experience, personality, cognitive style, and on the student's immediate interpretation. Instead, explicit and objective knowledge provides to all students equal possibilities to access and share the same knowledge whenever needed (Novak and Cañas 2008; Fabricatore and López in press).

The definition and provision of structured knowledge thus represents a pivotal challenge in design thinking education. We tackled this challenge in the domain of computer game design and development education through creating a bespoke knowledge representation tool, which we labelled game design knowledge map.

9.7 Game Design Knowledge Map: Structure and Rationale

A design knowledge map is a variant of concept map. Concept maps are visual representations of structured knowledge, articulated as graphs in which concepts are usually represented as nodes, and relationships between concepts as links between nodes (Novak and Cañas 2008). Concept maps are suitable to explicitly represent knowledge structures, and can help students to learn how to learn (Novak 2010). For this, concept mapping can be used in two ways: representation of evolving student knowledge, and mapping of expert knowledge provided to students (Novak and Cañas 2008; Novak 2010). In the first case, concept maps created and updated by learners serve to make their knowledge explicit as its construction process unfolds. This allows students to reflect on their knowledge structures, share them with others, and consciously modify them (Novak and Cañas 2008), facilitating an interplay between individual and collective learning processes which is key in open-ended problem solving (Fabricatore and López 2014). In the second case, expert skeleton maps are prepared by domain experts to facilitate the initiation of a knowledge construction process, and to scaffold the progressive assimilation and generation of new knowledge (Novak and Cañas 2008; Novak 2010). Knowledge construction unfolding through the exploration of a domain should be supported by reliable initial knowledge of that domain (Novak and Cañas 2008). Expert skeleton maps can be effectively used to model initial knowledge, creating scaffold structures based on which learners can construct new knowledge, assimilating, ideating and integrating new concepts and relationships (Novak and Cañas 2008). Scaffolding initial learning minimises the risk of introduction of misconceptions in the knowledge structures built by learners, and facilitates their remediation (Novak 2010). Furthermore, expert skeleton maps can foster the development of thinking strategies: by integrating knowledge about "what" experts think as well as "how" and "why" they think, skeleton maps can help students learn "how" to think as much as "what" to think.

To tackle the challenge of knowledge provision in the context of game design thinking education, we conceived the game design knowledge map as an expert skeleton map aimed at supporting knowledge construction throughout the game design and development process. For this, we conceptualised game design thinking as a human-centric problem-solving process (Fabricatore and López 2014, in press), aimed at addressing a specific core question:

- How can a game attract players, involve them in the game and keep them playing?

This question was formulated to explicitly represent the desired outcome of the game design problem-solving process (i.e. an engaged player), and therefore serve as focus question to support a meaningful exploration of the knowledge map (Novak and Cañas 2008).

In design thinking terms, our conceptualisation considers players as the key stakeholders of the problem scenario tackled by the game designer. Sustained engagement is then the key value to deliver to the stakeholders, and the game represents the system to be designed in order to deliver such value. Finally, the context of use is represented by the physical and social space which frames a gameplay activity but is not directly involved in it. The game design thinking process then requires to abductively hypothesize working principles defining, for a given target audience, which abstract gameplay activity aspects could be accessible, attractive and engaging, and why (e.g. challenge, reward, support, control, narrative, etc.) Games can be consequently created as systems of interacting elements suitable to promote the desired gameplay activity aspects, defining concrete features based on the hypothesized working principles. Designed features can be finally implemented and tested, in order to confirm or (re)defined game system features and engagement working principles, as need be. This creation process is carried out iteratively and incrementally, through cycles of design, implementation, testing, and evaluation, until the desired engagement value is generated.

According to this conceptualisation, our design thinking knowledge map integrated multi-disciplinary expert knowledge from the domains of computer science, game design and development, systems design and the social sciences, extrapolated from leading academic and practitioner literature. Embracing a human-centric approach, we determined that the knowledge to be included in the map had to be relevant to support design decision-making processes and cover the "what", "how" and "why" regarding:

(i) Users
(ii) Elements and patterns of organization of game systems
(iii) Elements and patterns of organization of natural contexts of use
(iv) Engagement principles that allow predicting and explaining how users may perceive and consequently interact with systems, in relation to their needs, preferences and contexts of use
(v) Approaches for testing impacts of a system on user and context of use

Nodes in the game design knowledge map encapsulate concepts reflecting key subproblems or activities involved in the user-centric game design endeavour, along with guiding questions conceived to orient and stimulate related reasoning, investigation, ideation of alternative options, and decision-making (Fig. 9.2).

In order to promote iterative and incremental exploration of the game design knowledge map, we defined its general structure based on a hierarchical star topology pattern. The core of the map covers four key activities involved in the game design endeavour:

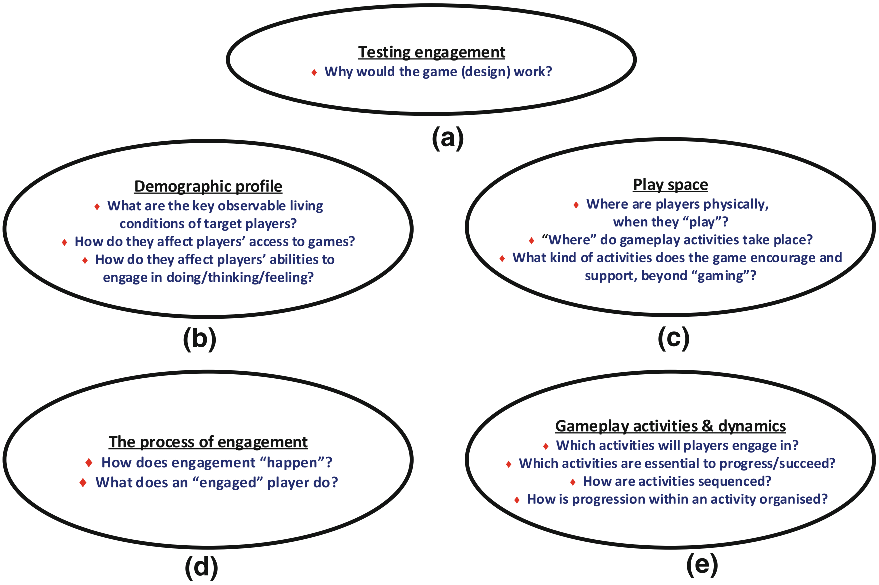

Fig. 9.2 Examples of nodes representing: **a** activity of the design endeavour; **b** sub-problem concerning the player; **c** sub-problem concerning context of use; **d** sub-problem concerning engagement working principles; **e** sub-problem concerning features of the game system

(i) Profiling target players: defining key characteristics of the target audience which may affect the way they perceive and interact with a game system.
(ii) Planning player engagement: identifying working principles suggesting which game aspects could trigger and sustain player engagement and why.
(iii) Designing the environment for engagement: analysing and defining features of the game system and its context of use to promote player engagement according to the working principles identified through (ii)
(iv) Testing engagement: prototyping/implementing features of the game system according to what designed through (iii), and testing to verify effects predicted according to the working principles identified through (ii)

Each node in the core represents a design activity with related guiding questions. Relationships between activity nodes represent their key logical relationships. Activity nodes and relationships were conceived to promote comprehension and exploration of what needs to be done, for what purpose, and how activities support one another throughout the iterative design process. Thus, the core of the knowledge map is overall aimed at supporting the student's assimilation of the whole design process, fostering the understanding of its core activities as much as the thinking underpinning their planning and execution (Fig. 9.3).

Each activity node is connected to a hierarchy of relevant design sub-problem nodes, along with guiding questions to orient related investigation and decision-making (e.g. Fig. 9.4). Sub-problems nodes reflect objectives to be tackled through

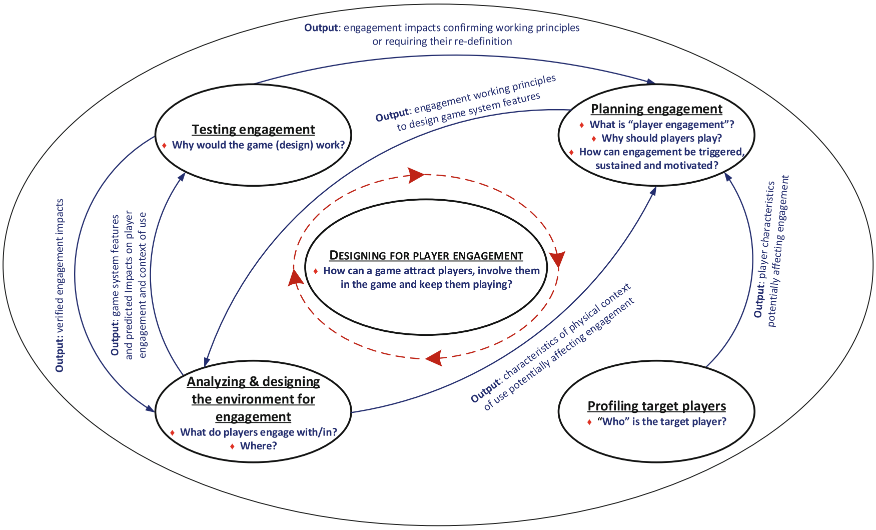

Fig. 9.3 Core of the game design knowledge map

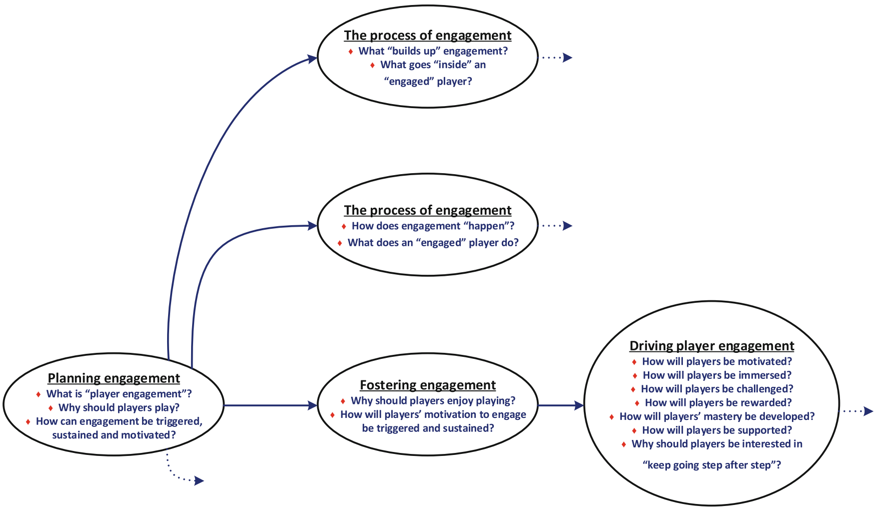

Fig. 9.4 Example of hierarchy of sub-problems

each activity, and have been defined to promote comprehension of which sub-problems a given activity might have to address, and reflection on what should be considered in order to address them.

For a given node, a game design knowledge map may provide additional knowledge to fully cover "what" to address, "how" and "why", through a 4-layered knowledge block (Fig. 9.5). The first layer of the block aims at promoting deeper reflection

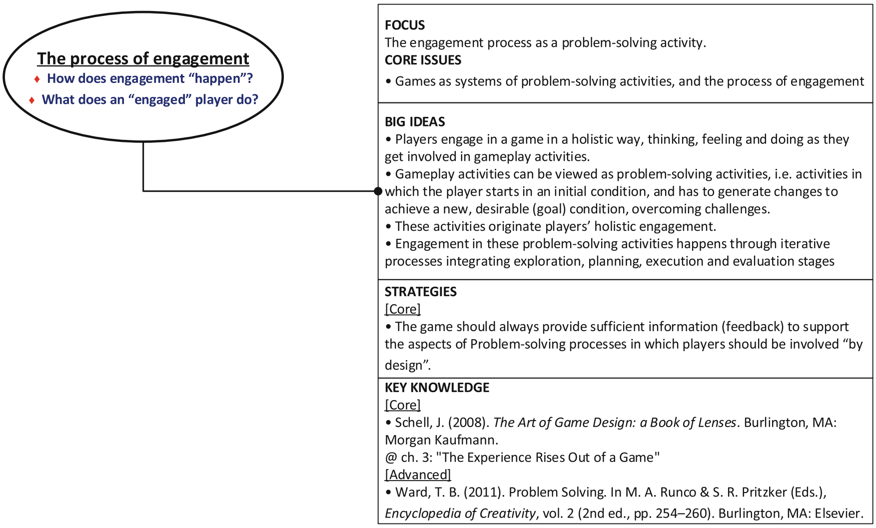

Fig. 9.5 Example of knowledge block

on "what", through outlining key foci and issues that should be considered when addressing the concept encapsulated in the node. The second layer aims at promoting deeper reflection and comprehension of "what" and "why", through presenting big ideas explaining the nature and importance of the issues presented in the first layer. The third layer aims at promoting deeper comprehension of "how" and "why" to tackle the issues presented in the first layer, accounting for the big ideas presented in the second layer. For this, appropriate strategies are provided (e.g. formal techniques, guidelines and principles). Finally, the fourth block aims at providing knowledge that directly underpin issues, big ideas and strategies, through presenting references to relevant literature and other sources (e.g. podcasts, webinars, etc.).

Overall, the organisation of the game design knowledge map was conceived to facilitate incremental exploration, assimilation and construction of operational knowledge throughout the design process, driven by its core activities and their outcomes. For this, knowledge was clustered so that the apprentice designer could easily assimilate, find and access it depending on the activity being planned or carried out, and the sub-problems tackled. Nodes and their related knowledge blocks were hierarchically organised so that their incremental exploration could drive incremental understanding of activities and sub-problems, and acquisition of conceptual tools to tackle them. Finally, the structure of the knowledge map was underpinned by a rationale of "operational incrementality and immediacy". On the one hand, the deeper the exploration of the hierarchy of nodes and related knowledge blocks, the greater the possibility to gain a deeper, more detailed understanding of design sub-problems, possibilities to tackle them and underpinning rationales. On the other hand, each node and each layer of the related knowledge block was planned to contribute by itself knowledge immediately useful to progress the design process: students to not need to explore the whole map to gain benefits, as each node may represent an opportunity to reflect and design "more" or "better".

9.8 Impacts of the Game Design Knowledge Map: Some Preliminary Results

We developed the game design knowledge map and used it in a range of game design and development modules delivered at the School of Computing and Engineering of the University of Huddersfield (UK). The version of the map discussed in this study was developed in 2014, and used in 2014–15, 2015–16, 2016–17 and 2017–18, in a total of eight level five and four level six modules of a BA Game Design programme (second and third undergraduate year, respectively).

A master map was created to comprise and integrate all the contents covered by all modules, to promote continuity and transferability of learning for students attending different modules at different levels. Then, for each module there was a specific map, consisting in the portion of the master map that addressed the intended learning outcomes of that module. Thus, for each module the map was made available in two versions: module-specific, strictly covering the contents of the module's syllabus, and the entire master map.

Each year the master map has undergone updates to ensure currency of contents (e.g. updating examples), address clarity issues (e.g. clarify phrasing), or update examples. This, however, has not significantly changed the structure of the knowledge map, nor its core contents.

For each module both versions of the knowledge map were made available to students online, through the University virtual learning environment (Blackboard). Students had the option to consult the maps online or download and use them offline.

The use of the map was not mandatory, and alternative resources were made available to access the required information through the virtual learning environment (e.g. lecture slides and notes from former editions of the modules, official module readings, etc.).

For all the modules the academic year was articulated in 24 sessions, on a weekly basis (excluding holiday breaks). During the first seven to nine sessions tutors used the map to introduce core contents, i.e. the ones essential to fulfil the module learning outcomes and corresponding to the module's syllabus. Core contents were presented through a combination of seminars, case studies and guided workshops.

For the remaining weeks students worked exclusively on a game project based on a brief provided at the beginning of the academic year. The project was articulated in two or three of formative milestones (depending on the module) and one final summative milestone. Formative milestones had the main purpose of reviewing project progression and providing formative tutor feedback to provisional project outcomes. Such feedback was based on contents of the knowledge directly related to provisional project outcomes, as well as contents not apparently leveraged in the project, but which could orient future developments. Project workshops were run between milestones. These represented an instance to promote peer testing and discussion of projects, as well as further provision of tutor formative feedback, all based on the contents of the knowledge map (module-specific or master, depending on what individuals or groups of students decided to use).

In each module students were required to document their design work through a combination of written and visual materials, according to some module-specific requirements. For this, a module-specific template was provided to them, with guidelines to define and organise contents in a structure that reflecting the contents and organisation of the appropriate module-specific version of the game design knowledge map. Students were also required to produce a structured project journal, documenting key decisions and reflections on the production process and state of the project after each milestone. The journal was structured so that students were encouraged to reflect on their project using contents of the module-specific knowledge map as "lenses" to evaluate their design decisions and their implications.

We are currently investigating data regarding the impacts of this strategy, and the specific influences that the game design knowledge map has had on the student learning experience. In this chapter, we present the results from 51 second-year students that used the knowledge maps in two game design and development modules during the academic year 2014–2015. Participants were predominantly male (84.3%) with a mean age of 21.2 (SD = 2.49). Students who were enrolled in both courses had access to the module-specific knowledge map and to the same master map. At the end of the academic year, students completed a module evaluation questionnaire, which included an open-ended question asking about the main positive aspects of the knowledge maps. The qualitative data gathered through this question were analysed using a content analysis procedure as described by O'Cathain and Thomas (2004). Thematic categories were identified and coded by the two authors, who jointly decided the categorisation scheme, individually classified the comments and discussed coding disagreements until consensus was reached. Coded comments were then subject to descriptive quantitative analysis to identify trends in students' opinions.

Results are presented in Table 9.1. Several positive aspects were perceived by students, among which three can be identified as major trends:

a. **Enhance accessibility of knowledge**. More than 60% of students expressed an appreciation for the quantity, clarity and ease of access of the information available in the knowledge maps. Many students valued the presentation of a large amount of information in a well-structured format, which made contents easy to understand and quick to find. Examples of students' comment were: "*It provided a quick and easy access to information to help us*"; "*Easy to follow*" and "*It had all the information in an easy way to understand it*". These results are in line with literature indicating that organisation of knowledge is as important as the content, since the structure of information implicitly embeds methods to approach and manipulate that knowledge (Cross 2001; Kokotovich 2008; Oxman 2004). The results suggest that the knowledge maps were structured in a way that

Table 9.1 Positive aspects of the Knowledge maps identified by student

Category of comment	N (total n = 51)	Frequency (%)
Cognitive and operational accessibility of knowledge	33	64.7
Quantity, clarity and structure of content	30	58.8
Ease of access	3	5.9
Support for thinking	22	43.1
Support for conceptualisation and analysis of the design situation	13	25.5
Support for formulation of rationale	5	9.8
Support for ideation of solution	5	9.8
Support for planning and execution of design process	10	19.6
Support to structure and produce design documents	9	17.7
Support to fulfil module requirements	4	7.8
Support for collaborative processes (organisation of teamwork, definition of shared goals)	3	5.9
Support for interestingness and enjoyment of design process	1	2.0
Transferability to other courses/domains	1	2.0
No comments	5	9.8

enabled the cognitive and operational access to the information, facilitating its use and application in the design process.

b. **Support for thinking**. About 44% of students perceived that the knowledge maps supported their thinking processes, helping them to structure their ideas and analyse the design problems tackled. Some students made general comments about the support provided by the knowledge maps, like "[It] a*sks enough questions to get you thinking*" and "*Helps to guide your thought processes*". Other students reported more specific descriptions of the cognitive process aided by this tool. Among these, most students' comments were related to the usefulness of the knowledge maps to conceptualise and analyse the design situation. They observed that "*The breakdown of questions made it easier to understand and analyse [the problem]*", "*helped me to concisely explain my ideas*", "*link different topics*" and "*made my study easier—more informed ideas + clearer rationale in my work*". Previous studies (e.g. Kokotovich 2008; Mathias 1993) have compared thinking strategies of novices and experts, finding that novices often rush towards a design solution based on insufficient analysis and understanding of the design problem to be tackled, evidencing shallower and less structured thinking processes. Conversely, the experts' approaches presented most of the features of design thinking, described as iterative, systemic-oriented, and acknowledging

> the complex relationship between design elements. In this regard, the knowledge maps emerged as valuable tools to support students in their design thinking, promoting the organisation of their analyses in a more reasoned, systematic and deeper way.

Students also highlighted the role of the knowledge maps in supporting the planning and execution of the design process, as well as the production of design documents. Representative examples of comments were that it "*offered a lot of information to help in the design process*", "*the work was more manageable by using them*", and "*the map allows organization of the project and makes it more efficient*". Although these topics were less frequently mentioned by students, we believe they represent further indicators of benefits of using the knowledge maps. These results suggest that knowledge maps helped student not only to understand "what" to do, but also "how" to do it, directing students towards more appropriate strategies and methods for accessing and handling the design knowledge.

9.9 Conclusive Reflections

In this chapter we have discussed the importance of human-centrism in modern computing, and the consequent need of adopting human-centric perspectives in CS education. We have emphasized the necessity for CS education to foster design thinking, being this a systematic problem-solving strategy key to conceive human-centric computing technologies suitable to address meaningful human needs in complex, ill-defined problem contexts. Accordingly, we have highlighted the importance and difficulty of imparting explicit, structured knowledge to support student learning regarding "what" to think, as much as "how" to think and "why". We have then proposed our approach to tackle such challenge of in the context of game design and development education: game design knowledge maps.

Game design knowledge maps are a variant of hierarchical concept maps, conceived to integrate and structure multidisciplinary knowledge regarding game systems, players, player engagement principles, and design and testing processes. We have designed the structure of game design knowledge maps so that students can explore imparted knowledge iteratively and incrementally, driven by the design problem-solving processes tackled and their provisional outcomes.

We have developed and tested game design knowledge maps for over four years, with encouraging results. The evidence analysed so far indicates that knowledge maps integrated large amounts of information in an easily accessible structure which fostered students' thinking processes, helped them connect themes and ideas, and guided them through the design process. All accounted for, this suggests that properly structured imparted knowledge can be effective in helping students to learn "how" to think, not just "what" to think.

Looking onwards, we plan of course to complete a thorough investigation of impacts of game design knowledge maps that we have registered so far. We believe, however, that the applicability and potential benefits of design knowledge maps should be investigated in other domains as well. Although the information contained in game design knowledge maps is obviously domain-specific, their prototypical structure and underpinning rationale are not. Many are the fields in which design can be conceptualised as a human-centric problem-solving process that accounts for the needs of key human stakeholders, context of use and possible solution to address stakeholders' contextualised needs (Buchanan 1992). Similarly, analysis of users' profiles, needs and context, definition of engagement strategies, and design and testing of solutions are activities common to design processes in diverse fields (Buchanan 1992; Dunne and Martin 2006). Hence, we believe that design knowledge map could be valuable tools to impart structured knowledge and foster design thinking in fields many other fields focussed tackling human-centric ill-defined problems, such as engineering, environmental planning, economics, architecture, etc.

Furthermore, the rationale underpinning the knowledge maps is based on the assumption that human-centric design is a process that relies on the abductive formulation hypotheses linking contextualised stakeholders' needs, value to be generated in order to satisfy those needs, current state and functioning of stakeholders, and systems to be designed in order to generate the desired value. Therefore, we believe that variants of the knowledge map could be developed for any other fields of education in which students are required to tackle open and human-centric problems.

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