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CREATING INFOGRAPHICS BASED ON THE BRIDGE21 MODEL FOR TEAM-BASED AND TECHNOLOGY-MEDIATED LEARNING

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ABSTRACT

Aim/Purpose	The main aim of this study was modeling a collaborative process for knowledge visualization, via the creation of infographics.
Background	As an effective method for visualizing complex information, creating infographics requires learners to generate and cultivate a deep knowledge of content and enables them to concisely visualize and share this knowledge. This study investigates creating infographics as a knowledge visualization process for collaborative learning situations by integrating the infographic design model into the team-based and technology-mediated Bridge21 learning model.
Methodology	This study was carried out using an educational design perspective by conducting three main cycles comprised of three micro cycles: analysis and exploration; design and construction; evaluation and reflection. The process and the scaffolding were developed and enhanced from cycle to cycle based on both qualitative and quantitative methods by using the infographic design rubric and researcher observations acquired during implementation. Respectively, twenty-three, twenty-four, and twenty-four secondary school students participated in the infographic creation process cycles.

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Contribution	This research proposes an extensive step-by-step process model for creating infographics as a method of visualization for learning. It is particularly relevant for working with complex information, in that it enables collaborative knowledge construction and sharing of condensed knowledge.
Findings	Creating infographics can be an effective method for collaborative learning situations by enabling knowledge construction, visualization and sharing. The Bridge21 activity model constituted the spine of the infographic creation process. The content generation, draft generation, and visual and digital design generation components of the infographic design model matched with the investigate, plan and create phases of the Bridge21 activity model respectively. Improvements on infographic design results from cycle to cycle suggest that the revisions on the process model succeeded in their aims. The rise in each category was found to be significant, but the advance in visual design generation was particularly large.
Recommendations for Practitioners	The effectiveness of the creation process and the quality of the results can be boosted by using relevant activities based on learner prior knowledge and skills. While infographic creation can lead to a focus on visual elements, the importance of wording must be emphasized. Being a multidimensional process, groups need guidance to ensure effective collaboration.
Recommendation for Researchers	The proposed collaborative infographic creation process could be structured and evaluated for online learning environments, which will improve interaction and achievement by enhancing collaborative knowledge creation.
Impact on Society	In order to be knowledge constructors, innovative designers, creative communicators and global collaborators, learners need to be surrounded by adequate learning environments. The infographic creation process offers them a multidimensional learning situation. They must understand the problem, find an effective way to collect information, investigate their data, develop creative and innovative perspectives for visual design and be comfortable for using digital creation tools.
Future Research	The infographic creation process could be investigated in terms of required learner prior knowledge and skills, and could be enhanced by developing pre-practices and scaffolding.
Keywords	creating infographics, knowledge visualization, infographic design model, Bridge21 learning model

INTRODUCTION

New technologies are prevalent in nearly every facet of our lives and have led to new skills being required to function efficiently. Today, students must be empowered learners, digital citizens, knowledge constructors, innovative designers, computational thinkers, creative communicators and global collaborators (International Society for Technology in Education, 2016). They have unprecedented powers of creation and communication with new technologies, but they must be equipped to use this power in order to be future-ready, lifelong learners. In order to realize this, the development of digital literacy skills in students is a core challenge in modern education.

Digital literacy is defined as the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both technical and cognitive skills (Ameri-

can Library Association, 2013). Another widely used definition of digital literacy is the capabilities for living, learning and working in a digital society (Joint Information Systems Committee, 2014; Universities and Colleges Information Systems Association, 2014). To improve students' digital literacy skills, activities must be embedded in the curriculum that will enable them to deeply understand the digital environment (New Media Consortium and The Consortium for School Networking, 2017). Teaching and learning must include deeper learning approaches, the roles of teachers must be remodeled, and classrooms should be redesigned as technology-mediated student-centered learning environments.

Visualization technologies, which cover a wide range of visualizing information strategies from simple infographics to complex ones, are an under-developed area in education terms (New Media Consortium and The Consortium for School Networking, 2017). In order to thrive in a digital society, learners increasingly need to be visually and digitally literate. Visual literacy is a critical 21st century skill and is defined as "a group of acquired competencies for interpreting and composing visible messages" (Brill, Kim, & Branch, 2007, p. 55). In order to improve visual literacy skills, it is suggested that encouraging learners to practice reading or decoding visuals through analysis techniques, and writing or encoding visuals as a tool for communication, are worthwhile activities (Heinich, Molenda, Russell, & Smaldino, 1999).

Alongside individual visualization skills, collaborative visualization is becoming more important in terms of its power to allow group knowledge creation for effective interaction and communication. Learners need to visualize group knowledge collaboratively in order to work together. As two emerging areas, collaboration and visualization can be integrated by developing visualization techniques for collaborative learning settings (Isenberg et al., 2011). During collaborative visualization activities, learners create and share visual representations of data through group information processing activities. Those activities include different levels of engagement while viewing, interacting/exploring or sharing/creating visualizations.

This study focuses on the creation of infographics as a method of group knowledge visualization and proposes an effective infographic creation process model in a collaborative learning setting. This process involves integrating the infographic design model (Nuhoğlu Kibar & Akkoyunlu, 2018) into the Bridge21 model for team-based and technology-mediated learning (Lawlor, Conneely, Oldham, Marshall, & Tangney, 2016). In this respect, this study will stand out by proposing a step by step generic process model for collaborative visualization via infographic creation, which could be transformed into other collaborative visualization learning activities.

The studies that handle infographic creation as a learning strategy and focus on the infographic creation process are investigated and summarized in the literature review. From these studies, the features of the infographic design model are examined using an educational research design perspective. Following an extensive explanation of the infographic design model, the Bridge21 learning model is described. It constitutes the main structure of the collaborative learning process within the literature review. The Bridge21 learning model and the infographic design model have been comparatively examined, and a collaborative infographic design process has been developed for implementation. Three iterative cycles, based on an educational design research method, have been applied, and the process is improved in each cycle.

LITERATURE REVIEW

CREATING INFOGRAPHICS

As an effective way of visualizing complex information, creating infographics motivates learners to understand the content deeply and share their knowledge concisely. Infographics allow visualization of data or ideas in order to convey complex information that can be quickly consumed and easily understood (Smiciklas, 2012). They combine linguistic and non-linguistic systems in a sweet spot

(Krauss, 2012). This type of visualization can present a large amount of complex content in a big picture (Davidson, 2014; Lamb & Johnson, 2014). This approach can be more memorable than other visualization types (Borkin et al., 2013).

Creating infographics initially requires students to engage in research on a topic and then encourages their multimodal literacy knowledge and skills for generating their own meaning from complex information (Abilock & Williams, 2014). Assignments challenge students "to condense data, to present as much data as possible, and yet to find ways to most efficiently display that data" (Chong, 2012, p. 2).

This creation process happens effectively by sharing a fresh understanding of relationships in a visual format by selecting and arranging appropriate visuals, text and evidence which was obtained through deep research (Abilock & Williams, 2014).

In order to create infographics, students must first be familiar with the terms and definitions related to the topic which will provide their knowledge base. They must recognize the various elements of infographics and the function served by each one (Chiliban, Căuneac, & Chiliban, 2014). Students will focus on understanding the role of these elements and then create simple infographics to demonstrate this.

Infographic design fosters digital and visual literacies support self-reflection and covers three learning tasks: a design challenge, a research project; and an opportunity for developing technical fluency (Matrix & Hodson, 2014). Learners need to focus on a topic, engage with content critically and support their idea by selecting key illustrative points to create pictorial representations. They utilize their online search skills to review their topic, which triggers them to use further queries within more relevant databases. The use of graphic editing software tools encourages them to develop their digital design skills. While viewing their peers' infographics, they decipher visual messages and communicate in a multimodal way.

Creating infographics triggers critical thinking on how to convey information in different ways, including graphs, charts, narratives, descriptions, icons, and images (Dyjur & Li, 2015). Subsequently, this encourages them to focus on how to use and arrange design elements, such as color, white space, text boxes, arrows, fonts, and assembling their project by using their digital media skills.

Creating infographics is an engaging experience, both in carrying out the research project and presenting the results to their peers. This includes determining the essentials from an information stack and finding evidence for supporting their idea (Davidson, 2014). Creating infographics fosters their information literacy skills by allowing them to practice effective methods for filtering information to reach credible sources and where to find copyright-free images or how to make their own. They learn how to organize, interpret and eliminate data during this process. Learners also develop their subject-specific literacy skills, e.g. science literacy skills, by interpreting surveys, laboratory investigations, and interviews conducted with experts. By creating digital infographics, students develop their media and digital literacy. In an attempt to reach the appropriate combination of information and artwork, digital tools allow them to create quickly and give them the chance to revise easily until they reach their goal.

Creating infographics is as an original way for refining students' writing, researching and visual storytelling skills. This encourages concise writing (Gallicano, Ekachai, & Freberg, 2014). In order to find visually appealing data, students work hard to find essential facts, which also helps develop their research skill in identifying credible sources. Creating infographics provides an opportunity for students to practice how to communicate visually, which is a valuable skill nowadays. In other words, creating infographics is the process of researching and writing as creating, which fosters design thinking skills, including information literacy, ethics, and creating for others (Mendenhall & Summers, 2015). Students create infographics by synthesizing and relating multiple resources and constituting their own meaning without oversimplifying. They need to make strategic choices on their research findings and

think about how to gather images and texts for representing the findings in the form of an informative and intriguing story (Thompson, 2015).

As it is seen from the literature review, infographic creation has, to date, been treated as an individual learning activity (Abilock & Williams, 2014; Chiliban et al. 2014; Davidson, 2014; Dyjur & Li, 2015; Gallicano et al., 2014; Matrix & Hodson, 2014; Mendenhall & Summers, 2015; Nuhoğlu-Kibar & Akkoyunlu, 2014, 2015; Thompson, 2015). No studies were found that handle infographic creation for collaborative learning settings.

In this approach, a design-based research method was used to examine the infographic design process. The individualized infographic design process model that is suggested in the infographic design model is adapted for use with the team-based and technology-mediated Bridge21 model in order to develop a collaborative infographic design process.

Infographic Design Model

The infographic design model consists of three main components: content generation, visual design generation and digital design (Nuhoğlu-Kibar & Akkoyunlu, 2018). According to the proposed infographic design process, learners should first generate content, then prepare the draft of the infographic and then move on to the visual and digital design phase (see Figure 1). Learners should understand their content well in order to visualize the information effectively, and they need a working knowledge of some digital tools to generate their infographic drafts. The proposed infographic design process is comprised of four stages: content preparation, a lecture on creating infographics, content and draft generation, and design generation. It is suggested that the whole process should be supported with feedback. The model is constructed using a generative learning theory (Grabowski, 2004) and its generative activities and information design principles. The most important stage of the process is content and draft generation. It consists of several steps, which include: investigation and systematic organizing of information, determining relationships between information components, emphasizing the essential information, generating layout, titles, and short descriptions.

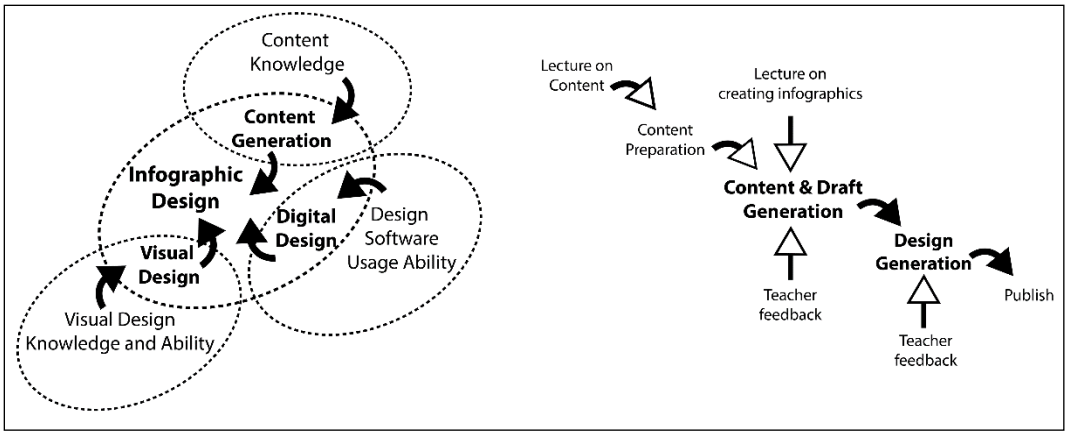


Figure 1. Infographic design model components and the infographic design process (Nuhoğlu-Kibar & Akkoyunlu, 2015)

Bridge21 Activity Model

The Bridge21 model is a social constructivist approach to teaching and learning that incorporates team-based, technology-mediated and project-based components (Nuhoğlu-Kibar & Akkoyunlu, 2018; Tangney, Oldham, Conneely, Barrett, & Lawlor, 2009). The components of the model are shown in Figure 2(a). The model recommends teamwork using shared technology by defining project-based learning activities, which allow teams to collaborate and manage their own learning. The role of the teacher is to act as a facilitator or guide, and the learning space and technology resources

are deployed to support this approach. For example, a team of four students sit around a table facing each other, sharing two devices. The relationships between the teammates are an important part of the learning process, and each team must make decisions together to complete their task successfully. Reflection is an important element of the Bridge21 model too. At the end of each project cycle, students reflect on their work, individually or with their team. This model has been shown to help students develop a range of skills such as collaboration, communication and creativity and to help increase their levels of motivation for learning (Lawlor, Conneely, Oldham, Marshall, & Tangney, 2018). For the students, it is a structured approach to completing a project in a team. The stages of this process are described in the Bridge21 activity model in Figure 2 (b).

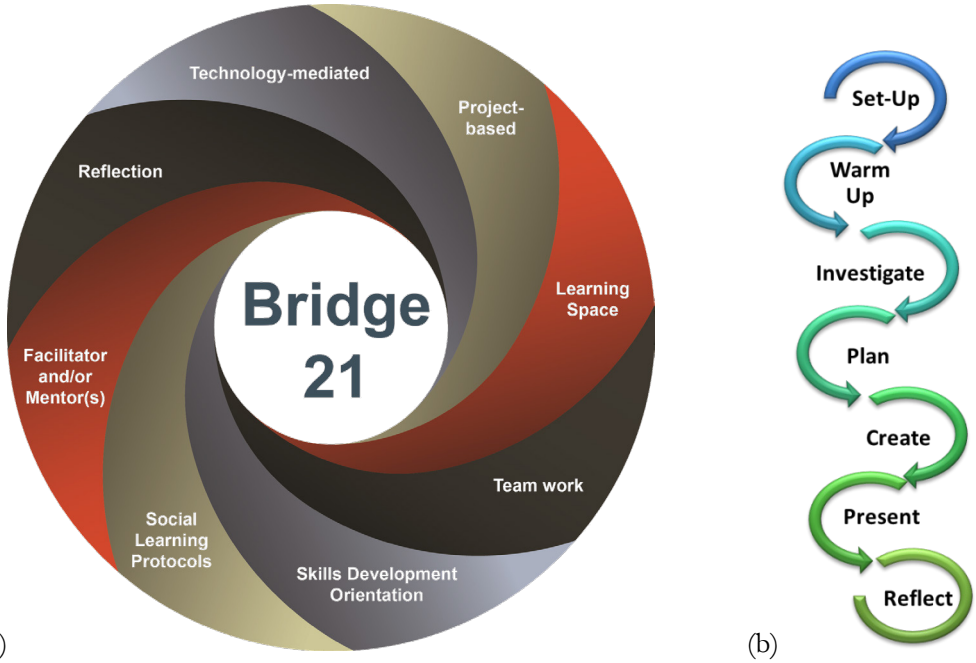


Figure 2. (a) The Bridge21 learning model (Bridge21, 2016) and (b) the Bridge21 activity model (Byrne, Kearney & Sullivan, 2019)

The Bridge21 activity model is comprised of set-up, warm-up, investigate, plan, create, present, and reflect phases (Lawlor, Marshall, & Tangney, 2016). The set-up and warm-up phases include team formation, introducing a new topic or reviewing prior knowledge and introducing new tools or techniques that may be useful for the project. Through the investigate phase, the teacher defines the problem context and the teams brainstorm ideas, explore content and carry out research. In the plan phase, teams focus on designing solutions, assigning roles among themselves and scheduling. In the create phase, the artefact is created (this may be an iterative process). At the end, teams present their artefacts to their peers and reflect on their experiences.

One interesting aspect of this teamwork model is the use of team leaders. Each team elects a team leader, who fulfills that role for the duration of the team's stay in Bridge21. This could be a single day, a week or several workshops over a longer period. The role of the team leader is primarily about communication. The facilitator will call several meetings each day with the team leaders to check in on progress, make decisions or provide additional information. This process allows the students to take responsibility for their project.

RESEARCH METHODOLOGY

The main aim of this study was modeling a collaborative process for knowledge visualization, via the creation of infographics. The process model was developed, based on theory and acquired experi-

ences, through an educational design research perspective, by integrating the infographic design model (Nuhoğlu-Kibar & Akkoyunlu, 2018) into the team-based and technology-mediated Bridge21 learning model (Lawlor et al. 2016).

The main research question was: "How should we model a team-based, technology-mediated process for knowledge visualization through the design of infographics?" Two subquestions were examined at the end of all three cycles, which were: "What levels of infographic design are present in the student work as measured by the infographic design criteria?" and "Did the teams face any obstacles during the infographic design process?"

This study was carried out using an educational design research method (McKenney & Reeves, 2012) which aims to develop a product, process, program or policy, oriented at both the theoretical and applied perspective of learning. The research process was carried out within real life situations through a flexible and iterative approach by collaborating with the stakeholders. The intervention was iterated until a certain level of effectiveness with regard to learning requirements was reached.

The educational design research generic model consists of three core phases. Each meso cycle comprised of three micro cycles. The micro cycles were: analysis & exploration, design & construction and, evaluation & reflection (McKenney & Reeves, 2012, p. 76). The research was conducted by integrating research and design processes in order to put forth theoretical and practical outcomes in a flexible and iterative structure. The whole research process began with an analysis and exploration cycle. A literature review was conducted to understand the problem and generate design requirements. During the design and construction cycle, a conceptual model of the intervention was constructed. The meso cycle ended with an evaluation and reflection micro cycle. The conceived model was evaluated through an intervention, and then the findings were investigated in order to reach redesign ideas and conclusions for the following meso cycle. In order to answer research questions, a combination of quantitative and qualitative methods was used within the evaluation and reflection micro cycle, including focus group interviews, observations, questionnaires/checklists, (pre/post) tests, logs/journals and document analysis (McKenney & Reeves, 2012, p. 147).

This study aimed to explore group knowledge visualization and to examine a process model for creating infographics through team-based classroom activities using a design research generic model. The research model was developed through three iterative meso cycles, which comprised of analysis & exploration, design & construction, evaluation & reflection micro cycles. The research model was designed and implemented through a co-learning agreement (Wagner, 1997). This is a systemic approach during which researchers and practitioners participate in both implementation and reflection.

The first analysis and exploration micro cycle was the most intensive one. It included the detailed literature review, and in-house activities were conducted on creating infographics and the Bridge21 learning model. The previous studies on infographic design model and the Bridge21 learning model constituted the theoretical basis of the research model. In-house activities on both models constituted the practical basis of the research model.

The intervention of creating infographics based on the Bridge21 learning model was designed using a structured framework during the analysis and exploration cycle. The intervention was evaluated and reflected upon before the following meso cycle in order to enhance the design. The evaluation and reflection cycle of the research was conducted through a mixed method design by using an infographic design rubric and observations. The design was developed through two following meso cycles comprised of both analysis & exploration, design & construction, evaluation & reflection micro cycles.

Research Group

The study was conducted in three cycles. The first meso cycle included 23 students (13 females, 10 male). The second meso cycle included 24 students (14 females, 10 male). The third meso cycle in-

cluded 24 students (15 females, 9 male). All students were 15 or 16 years old and attending secondary school. In every cycle, students were grouped into teams of 4. Where possible, mixed gender teams were created and students from the same school were assigned to separate teams. Beyond this, team selection was random. One facilitator led each session, with support from two or three volunteer adult mentors.

Each intervention was completed within one day, over three weeks of the Bridge21 programme in November 2016. The Bridge21 programme is an out of school education programme which takes place in a collaborative learning space in Trinity College Dublin. Students spend four days, during school hours, working and learning together. The programme involves students completing multimedia projects, such as video editing, sound editing or web design. For most of the students, this was their first experience creating digital artefacts. The infographic activities took place on day three of four, for each group. None of the group had created an infographic prior to these workshops.

Research Environment

Based on the Bridge21 learning model, the learning space was customized for collaborative studies. The space consisted of two rooms. One room was a flat space with moveable tables and chairs and a large screen and projector (see Figure 3). This allowed for presentations, whole group discussions and teamwork. The day typically began and ended in this room with setup and planning happening here and then the team presentations and reflection at the end of the day.

Figure 3. Photos from the first room

The second room (see Figure 4) featured divided work spaces for each team. There were six semi-enclosed work areas, or "pods", one for each team. Each pod contained two desktop computers and chairs for a team of five. This allowed the teams to work on their projects, access the internet and create artefacts while encouraging collaboration.

Figure 4. Photos from the second room

Data Collection Tools and Data Analysis Procedure

Infographic Design Rubric (IDR)

The Infographic Design Rubric (IDR) was the main data collection tool, which provides a framework on infographic creation as well as for evaluating the infographics and infographic design process in turn (Nuhoğlu-Kibar & Akkoyunlu, 2017). Covering the whole infographic creation process, the IDR is comprised of two main dimensions: content generation and visual design generation. These include 32 items with four performance level descriptions (one to four) for each one (Table 1). The four performance levels correspond to unacceptable, needs work, competent, and exemplary, respectively.

The infographics were evaluated by the researcher, who has expertise in creating infographics as a learning strategy in terms of theoretical background and practical implementation. In order to avoid validity and reliability problems, an interrater reliability analysis using the intraclass correlation statistic was performed (Shrout & Fleiss, 1979). The consistency among raters was determined over evaluation of 11% of created infographics by another researcher with expertise in these areas. The created infographics were listed from 1 to 18 and two of them were selected using a random integer generator. In the two-way mixed average measure, the intraclass correlation coefficients were found to be significant ($p < .5$) for the infographics (ICC (3, 2) = 0.68 with 95% CI (0.47, 0.80)).

Table 1. Infographic design rubric dimensions and items

CONTENT GENERATION	VISUAL DESIGN GENERATION	
Main Heading	**Big Picture**	**Colors & Visuals**
Sub-headings	Visual Hierarchy	Color effect on visibility of inf.
Grouping	Redirection	Color Harmony
Systematics	Rhythm	Color effect on redirection
Consistency	Emphasis	Background Color
Essential Inf.	Consistency	Visual Reflection of Inf.
Key Concepts	Balance	Reality level of visuals
Descriptions	Integrity	Tags of visuals
Exemplification	**Text**	
Outcome	Font Type	Line Length
Identity	Font Color	Line Spacing
	Font Size	Justification
	Font Case	

Observation Form

In order to determine the strengths, weaknesses, opportunities and threats of the infographic creation process, semi-structured observation forms were developed based on a Strengths, Weakness, Opportunities, and Threats (SWOT) analysis structure. Taking its roots from strategic management studies, SWOT analysis enables an analysis of a process or situation in terms of its strengths and weaknesses in order to identify opportunities and minimize the effect of threats by "listing favorable and unfavorable internal and external issues in the four quadrants of a grid" (Helms & Nixon, 2010, p. 216). In this study, a SWOT analysis based observation form was used for obtaining a more expedient determination in the analysis and exploration micro cycles in order to develop the process design.

The observation form was comprised of questions designed to determine strengths and weaknesses such as "What was easy to do for the students along the whole process?" and "What was difficult to do for the students along the whole process?". In order to determine the opportunities and threats within the intervention, questions such as "Which interventions made the infographic process easier?" and "Which interventions made the infographic process difficult?" were included. The focus of the observation form was to determine complicating steps or points for improving the infographic creation process model. The observation notes were taken during the workshops. In order not to interrupt the workshops, one of the researchers was responsible for completing the observation form by interacting with the mentors during the workshops.

Meso Cycle Analysis

First Meso Cycle

Analysis and exploration. This first analysis and exploration micro cycle of the research was the most extensive, covering detailed observations and analyses. In order to examine the probable relevance between creating infographics and the Bridge21 learning model, the analysis and exploration micro cycle began with a seminar in which researchers roughly analyzed and brainstormed on the

integration of the infographic design model into the Bridge21 learning model. In this broad seminar, implications on the design of the infographic creation process based on the Bridge21 activity model were gathered. After this seminar, a four-day Bridge21 workshop was observed in order to explore the operational structure of the activity model.

Design and construction. Similar to the first analysis and exploration micro cycle, the first design and construction micro cycle was the most extensive of the design cycles. In the design and construction micro cycle, the individual infographic creation structure of the infographic design model was analyzed and transformed into a collaborative structure. This was done by organizing the steps of the infographic design model according to the Bridge21 activity model phases. The intertwined infographic design model components and the Bridge21 activity model phases constitute the framework of the process. The content generation corresponds to the investigate phase, draft generation corresponds to the planning phase, visual and digital design corresponds to the create phase.

Besides the process design, materials and environment preparation were carried out. The visual infographic design rubric was developed, which constituted the most essential scaffolding material for the process. While developing the visual infographic design rubric, IDR was used as a base and then simplified as much as possible without losing content. To prepare the learning environment, an infographic library was created on Pinterest. Two infographic examples with different quality and features were chosen for discussion and user accounts were created in Pinterest and Piktochart.

The Workshop Structure. The workshop consisted of warm-up, investigate/content generation, planning/draft generation, create/visual and digital design, present and reflect stages.

Warm-up: Students began the process by watching a short video on "What are infographics?". After a short discussion about the meaning of infographics, teams glanced through infographics on Pinterest, which were collected by the researchers. Teams then evaluated two infographic examples using the Visual Infographic Design Rubric (see Figure 5).

Investigate-Content Generation: The investigation-content generation phase began with brainstorming on "being a teenager in Ireland" and finding topics related to this area. After sharing topics, teams selected one topic to focus on for their project. Following a presentation on how to generate good questions to prepare a fruitful survey, teams focused on their chosen topic to generate five questions for their peers. They prepared their survey and distributed them among the other teams. They completed the investigation phase by analyzing their data and gathering appealing findings.

Planning-Draft Generation: The planning-draft generation phase began with watching a short video on "What is Piktochart?". After watching the video, teams prepared their drafts on their whiteboards with board markers by determining the fields (Gridding), deciding on main and sub-headings and choosing a method of visualization. Teams focused on how to organize and visualize their most important findings.

Create-Visual and Digital Design: In the creation-visual and digital design phase, teams created their infographics by using an online infographic design tool, Piktochart. Teams began by choosing a template and determining the layout. They determined the fields on a digital board, placed the headings and orientation elements, wrote the explanations, visualized information and placed their identity (the information about creators, creation date and references).

Present & Reflect: Teams evaluated their infographics by using the visual infographic design rubric and reflected on their infographic design process. At the end, teams presented their infographics to the other teams.

The mentors helped to guide the teams by checking in with them regularly, and the lead facilitator oversaw the process with quick operational meetings with the team leaders.

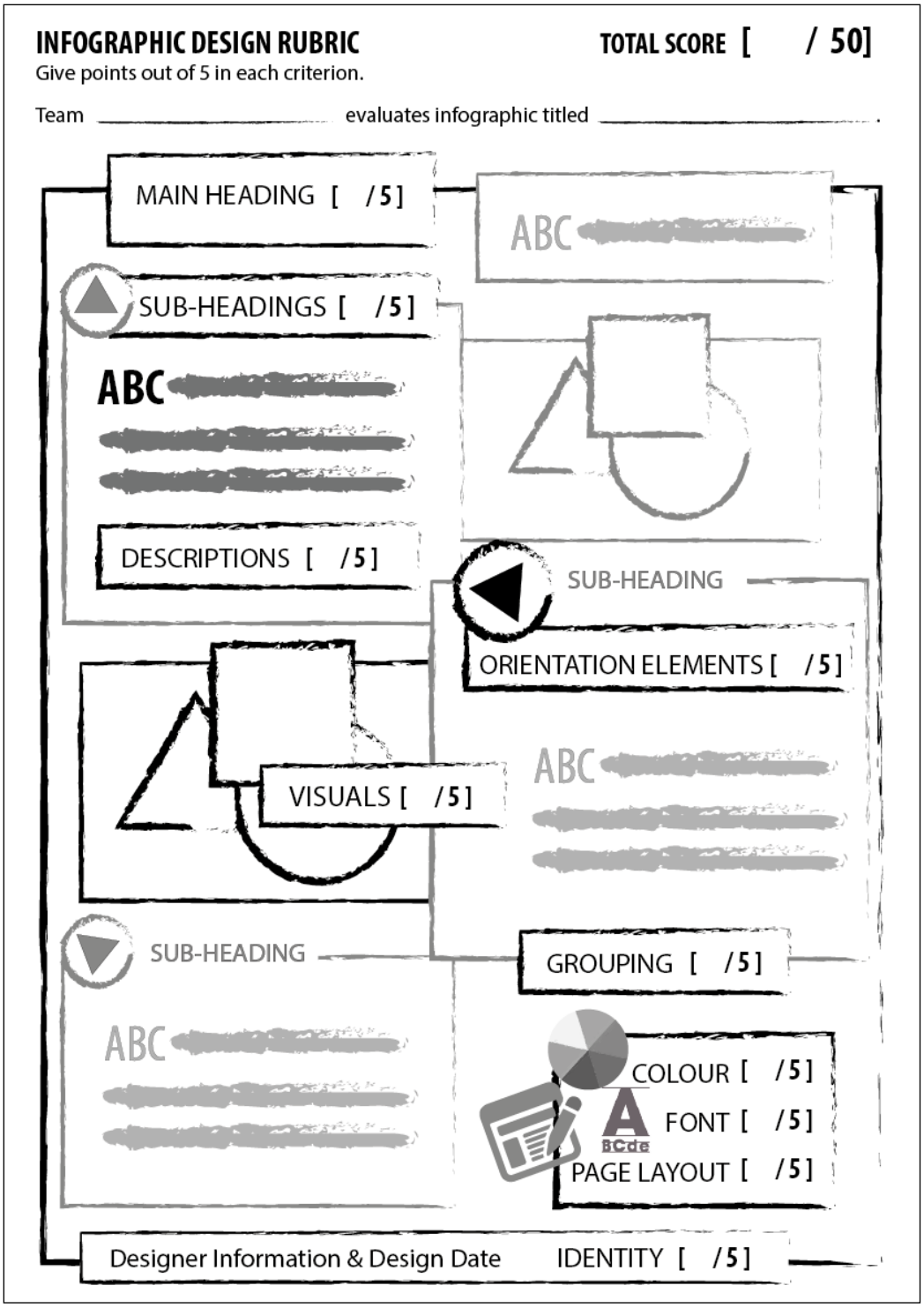


Figure 5. Visual infographic design rubric

Evaluation and reflection. Infographic design results (M=2.65, SD=0.13) showed that both content generation (M=2.65, SD=0.39) and visual design generation (M=2.65, SD=0.19) performance needed improvement. It can be seen from Table 2 that the rubrics were evaluated between "needs work" and "competent" performance levels in most of the items. The highest ranks obtained within content generation were for grouping, sub-heading and outcome, and within visual design generation

were redirection, font color, line length, line spacing, justification and background color. In terms of overall results in the 1st meso cycle, it could be seen that most of the content generation, the big picture and the color and visuals of the design ranked lower than three and needed to be improved.

The most important observation recorded was the teams' hurriedness to pass through to digital design, and reluctance to develop their drafts on whiteboards just after watching online tool videos. Because of the importance of creating drafts, it was decided that watching the "What is Piktochart?" video needs to occur after drafting on the whiteboards.

The other observation was about the evaluation of infographic examples, which is essential for improving the understanding of infographics and line of vision. Teams preferred to evaluate infographics by dividing those two examples between members instead of viewing together, which constrained them from comparing, discussing and seeing the difference between examples. The most difficult thing was convincing teams to write descriptions into their infographics, which should be focused on.

Table 2. 1st meso cycle infographic design results

CONTENT GENERATION			VISUAL DESIGN GENERATION					
	M	*SD*		*M*	*SD*		*M*	*SD*
Main Heading	2,66	1,50	**Big Picture**	**2,54**	**0,24**	**Colors & Visuals**	**2,52**	**0,28**
Sub-headings	3,83	0,40	Visual Hierarchy	2,50	0,54	Color effect on visibility of inf.	2,00	0,00
Inf. Organization			Redirection	3,00	0,00			
Grouping	3,16	0,98	Rhythm	2,66	0,51	Color Harmony	2,00	0,00
Systematics	2,16	0,75	Emphasis	2,50	0,54	Color effect on redirection	2,33	0,51
Consistency	2,00	0,63	Consistency	2,33	0,51			
Inf. Quality			Balance	2,33	0,51	Background Color	3,00	0,89
Essential Inf.	2,83	0,75	Integrity	2,50	0,54	Visual Reflection of Inf.	2,66	0,51
Key Concepts	2,66	0,81	**Text**	**2,90**	**0,35**	Reality level of vis.	2,33	0,51
Descriptions	2,33	0,51	Font Type	2,66	0,51	Tags of visuals	3,33	1,03
Exemplification	2,16	0,75	Font Color	3,66	0,81	**Visual Design Generation**	**2,65**	**0,19**
Outcome	3,00	0,89	Font Size	1,50	1,22			
Identity	2,33	1,50	Font Case	2,33	0,51			
Content Generation			Line Length	3,66	0,51	**Infographic Design**	**2,65**	**0,13**
	2,65	**0,39**	Line Spacing	3,00	0,89			
			Justification	3,50	0,83			

Second Meso Cycle

Analysis and exploration. Taking into consideration the infographic design results and observations during the 1st implementation, the design was improved by strengthening the scaffolding and arranging the structure of the process by adding or replacing the steps. The analysis of the process was begun during the implementation. The researcher had taken reflection notes about points at which teams had difficulty or couldn't have performed easily. Due to the nature of this research,

successive cycles of evaluation and reflection and the analysis and exploration cycles should be handled and utilized as interconnected. The required edits in the design process focused on two essential points: how to make teams concentrate on their drafts, and how to make them more literate about visualization.

Design and construction. To help students examine infographic terms in more detail, it was decided that the teams not be separated while evaluating infographic examples with the rubric, but for them to compare and discuss all together.

The most important change in the structure of the process was moving the Piktochart videos from the beginning of the planning phase to the create phase. This was done in order to prevent teams focusing on the online tool before developing their drafts. It was intended to help them concentrate more on their survey results and improve their content generation in turn.

One of the outstanding developments was adding a short presentation (~10 minutes) at the beginning of the planning phase, on tips about how to create effective infographics. The presentation was comprised of 25 slides full of infographic examples. During the quick presentation, it was aimed to make the teams focus and discuss more on infographic components and features. The presentation touched on these points: attractive and descriptive headings; concise and informative main description; orientation elements such as arrows, numbers, icons, colours; iconic visuals; visualizing numeric data; grouping with colours, tones, shapes, lines; choosing colours and generating a colour palette; integrity by using similar shapes in similar directions; background colour and contrast; choice of type face. In the create phase, teams were reminded about these points regarding their own designs.

The main incompetence or unwillingness among students was in writing main and short descriptions. To take their attention and make them spend more time on this point, a "main description" item was added to the visual infographic design rubric. Reminders about writing descriptions were given continuously during the workshop.

Teams were informed especially how to find icons from Piktochart and web libraries. Also, teams were encouraged to draw their own simple icons by using simple shapes.

Evaluation and reflection. Infographic design results from the 2nd cycle (M=3.07, SD=0.43) showed that both content generation (M=3.06, SD=0.34) and visual design generation (M=3.07, SD=0.62) performances mostly ranked over 3, which corresponds to competent (see Table 3). Based on the results in the 2nd meso cycle, it can be concluded that in almost every item, teams rated more highly than in the 1st meso cycle. However, there were items rated below 3 that should be improved upon. Within content generation, this included systematics, consistency, descriptions, exemplification, and identity. In visual design generation, areas for improvement included font type, font size, font case, color effect on visibility of information, color effect on redirection and background.

Table 3. 2nd meso cycle infographic design results

CONTENT GENERATION			VISUAL DESIGN GENERATION					
	M	*SD*		*M*	*SD*		*M*	*SD*
Main Heading	3,33	1,21	**Big Picture**	**3,09**	**0,78**	**Colors & Visuals**	**3,14**	**0,67**
Sub-headings	4,00	0,00	Visual Hierarchy	3,00	0,89	Color effect on visibility of inf.	2,66	0,81
Inf. Organization			Redirection	3,16	0,75			
Grouping	3,50	0,83	Rhythm	3,00	0,89	Color Harmony	3,00	0,89
Systematics	2,83	0,40	Emphasis	3,16	0,75	Color effect on redirection	2,83	0,75
Consistency	2,83	0,40	Consistency	3,16	0,98			

CONTENT GENERATION			VISUAL DESIGN GENERATION					
	M	*SD*		*M*	*SD*		*M*	*SD*
Inf. Quality			Balance	3,00	0,89	Background Color	2,83	0,98
Essential Inf.	3,33	0,51	Integrity	3,16	0,98	Visual Reflection of Inf.	3,50	0,83
Key Concepts	3,16	0,40	**Text**	**3,00**	**0,43**	Reality level of vis.	3,50	0,54
Descriptions	2,50	0,83	Font Type	2,83	0,98	Tags of visuals	3,66	0,81
Exemplification	2,66	0,81	Font Color	3,33	1,03	**Visual Design Generation**	**3,07**	**0,62**
Outcome	3,33	0,51	Font Size	1,50	2,00			
Identity	2,16	1,32	Font Case	2,83	0,98			
Content Generation	**3,06**	**0,34**	Line Length	3,66	0,51	**Infographic Design**	**3,07**	**0,43**
			Line Spacing	3,00	1,09			
			Justification	3,83	0,40			

Lack of time was the most important problem observed in the 2nd cycle. Teams had to be organized in order to manage their time while doing such a complex task. However, while they were trying their best working separately on elements of the project, they were still not organized well enough to solve multidimensional design problems such as creating an infographic.

Third Meso Cycle

Analysis and exploration. In the 2nd cycle, drafts were more developed before going through digital design. Teams seemed more literate while creating visuals and visual design generation results support this observation. Despite the upgraded infographic design results following the adjustments in the 2nd cycle, there were still design deficiencies. In order to address the time problem and support teams to create more advanced infographics, it was decided that it would be constructive to enhance the design with more scaffolding during setup activities and during the creation process. It was decided to deliver regular messages via the team leaders and to encourage the teams to collaborate more effectively, while also monitoring that collaboration more closely.

Design and construction. In the 3rd cycle, teams were given extra time to compare the sample infographics. The strong emphasis on this step was to make the learners think critically on infographic features, prior to creating their own infographics.

In order to find a solution to the time problems, to make every member of the team active and to enhance some of the previously missing features of infographic designs, guidance on collaboration was delivered to teams via the team leaders. Teams made their collaboration plan following this suggestion. This collaboration plan covered analysing data, finding meaningful and essential information groups, writing attractive and concise main title and sub-titles, composing short descriptions and a main description based on survey results, creating a layout, choosing a template, deciding colours, and finding or drawing icons.

Based on the teams' questions about Piktochart in the 2nd cycle and the points that they generally got stuck on, more short videos were added to the process in order to give tips on adding blocks and icons, customizing charts and importing data.

Evaluation and reflection. Based on the infographic design results (M=3.33, SD=0.30) of the 3rd meso cycle, it could be said that the improvement seen in the 2nd cycle was maintained. The overall grades could be evaluated as high, but with some categories still showing room for improvement. There were grades of 3 or lower for categories including descriptions, font type, font size, font case,

line spacing, color effect on visibility of information, color effect on redirection and background colour (see Table 4).

Table 4. 3rd meso cycle infographic design results

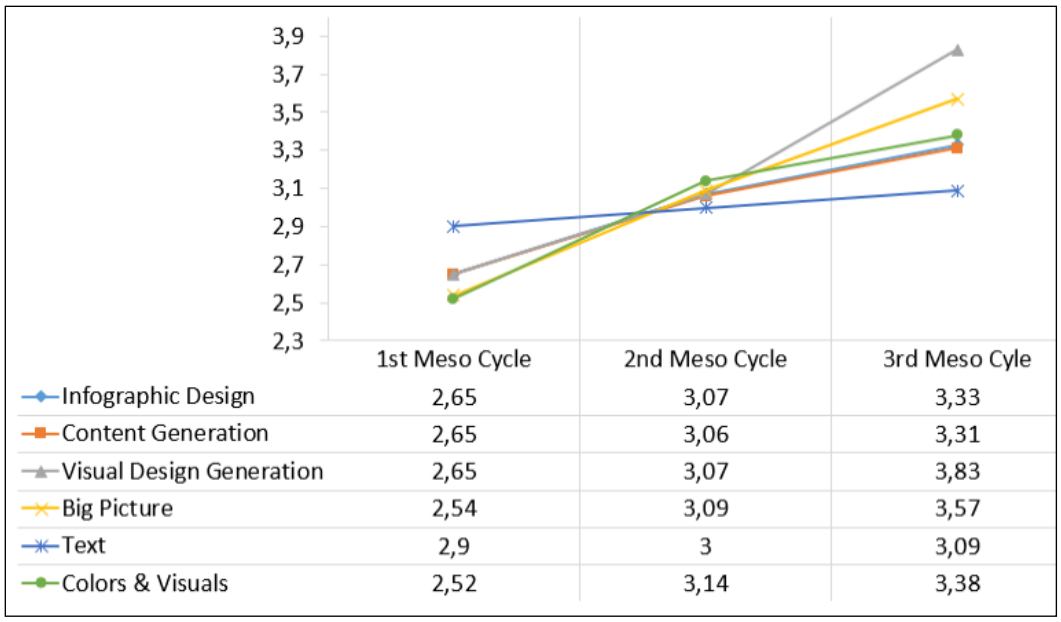
CONTENT GENERATION			VISUAL DESIGN GENERATION					
	M	*SD*		*M*	*SD*		*M*	*SD*
Main Heading	3,33	1,21	**Big Picture**	**3,57**	**0,52**	**Colors & Visuals**	**3,38**	**0,50**
Sub-headings	4,00	0,00	Visual Hierarchy	3,50	0,54	Color effect on visibility of inf.	2,83	0,75
Inf. Organization			Redirection	3,83	0,40			
Grouping	3,83	0,40	Rhythm	3,66	0,51	Color Harmony	3,50	0,54
Systematics	3,33	0,81	Emphasis	3,50	0,54	Color effect on redirection	3,00	0,89
Consistency	3,33	0,81	Consistency	3,33	1,03			
Inf. Quality			Balance	3,50	0,83	Background Color	3,00	0,89
Essential Inf.	3,33	0,51	Integrity	3,66	0,51	Visual Reflection of Inf.	3,66	0,81
Key Concepts	3,33	0,51	**Text**	**3,09**	**0,23**	Reality level of vis.	3,83	0,40
Descriptions	3,00	0,89	Font Type	3,00	1,09	Tags of visuals	3,83	0,40
Exemplification	3,16	0,98	Font Color	3,50	0,54	**Visual Design Generation**	**3,34**	**0,40**
Outcome	3,33	0,51	Font Size	1,83	0,98			
Identity	2,50	1,04	Font Case	3,00	0,00			
Content Generation	**3,31**	**0,31**	Line Length	3,66	0,51	**Infographic Design**	**3,33**	**0,30**

The most important observation in the 3rd meso cycle was the teams' reluctance to add descriptions into their infographics and uneasiness while generating and using colour palettes.

RESULTS

The designed models were evaluated in every cycle based on evolution of the infographic design results gathered with the infographic design rubric and observations determined by the researchers. Improvements on the infographic design results from cycle to cycle suggest that the revisions on the model succeeded in their aims (see Figure 6). The rise in each category is significant, but the advance in visual design generation is particularly large. Infographic examples that were created in the 3rd meso cycle are shown in Figure 7.

Font size, font case and line spacing results were still relatively low in cycle 3, which could be easily enhanced by pre-practices with a worksheet focusing on examples of font and line space. At the beginning of the create stage, just after writing some initial words, asking students to resize the area and find out if it is readable in a print preview version would be an effective way to find the ideal font size and line spacing. To put across the importance of descriptions, two or more sample infographics, with and without descriptions, could be shown to teams to reflect what they understand from those two versions.



	1st Meso Cycle	2nd Meso Cycle	3rd Meso Cyle
Infographic Design	2,65	3,07	3,33
Content Generation	2,65	3,06	3,31
Visual Design Generation	2,65	3,07	3,83
Big Picture	2,54	3,09	3,57
Text	2,9	3	3,09
Colors & Visuals	2,52	3,14	3,38

Figure 6. Comparative presentation of infographic design results of meso cycles

Figure 7. Infographic design examples from 3rd meso cycle

DISCUSSION

In this study, a collaborative infographic creation process model was developed for group knowledge visualization. Through conducted cycles, it is clear that in order to be an active collaborator in the infographic creation process, learners need to understand the problem, find an effective way to collect information, be part of discussions for analyzing the situation and proposing proper solutions, investigate gained data, have creative and innovative perspectives for visual design, and be comfortable using digital creation tools.

When the developed collaborative infographic design process is compared to the individual infographic creation process, it is especially clear that the content and draft generation phases are the most condensed collaborative parts of the whole process. These are phases during which group knowledge is constructed just before the visual and digital design generation begins. The knowledge construction launches with brainstorming on a topic, continues with generating survey questions on that topic, and condenses with analyzing data together and then finding connections. The constructed knowledge is then visualized collaboratively in draft generation.

Taking into account the multi-dimensional expected learning outcomes, the collaborative infographic creation process was modeled using an educational design research perspective. The starting point of the research involved comparing the theoretical basis and practical process of the infographic design model with the team-based and technology-mediated Bridge21 learning model and then generating a draft intervention design. The initial version of the model was improved through evaluations conducted over three implementations. The main difference between the first and third cycles was including guidance on collaboration, with the aim of focusing all the group members on the activity especially based on their skills. This difference was reflected in the visual and digital design generation phase, which is the main collaborative visualization part of the process. This was also emphasized throughout the workshop in order to improve their infographics. Additional guidance focused on writing attractive and concise titles, shortening descriptions, creating layout, deciding colors and drawing or finding icons. Analyzing the data retrospectively and finding additional relevant information was also suggested to the team through team leaders.

This study aimed to combine data visualization and collaboration. The determined improvement on the quality of the students' infographics and active contribution of each team member to the process from cycle to cycle can be interpreted as good indications of research results that meet research expectations. The improvement observed between the first and second cycles was two times more than that seen between the second and third cycles, and was consistent with the modifications that were made. From the second to third cycle, the observed improvement on team members' participation, following the collaboration plan that was delivered through team leaders, is another important indication that could be a starting point for future studies.

PROCESS MODEL OF CREATING INFOGRAPHICS BASED ON BRIDGE21 ACTIVITY MODEL

The main structure of the Bridge21 activity model comprises seven phases: set-up, warm-up, investigate, plan, create, present and reflect. These phases constituted the spine of the collaborative infographic design process. A first step was aligning stages of the infographic design model (content generation, draft generation, and visual and digital design generation) with the investigate, plan and create phases of the Bridge21 activity model (Figure 8).

The detailed design of the process model was developed through three meso cycles using an educational design research perspective. The collaborative infographic design process began with watching videos on infographic creation and evaluating infographic examples during the warm-up phase. Teams began content generation by brainstorming on a topic and sharing possible keywords with the others. The teams selected one theme to concentrate on for generating survey questions. The teams

then moved to their computers and prepared their survey. The surveys were then distributed, completed and collected. Corresponding to the investigate step, the content generation was completed with analyzing the data and compiling it by finding relations within.

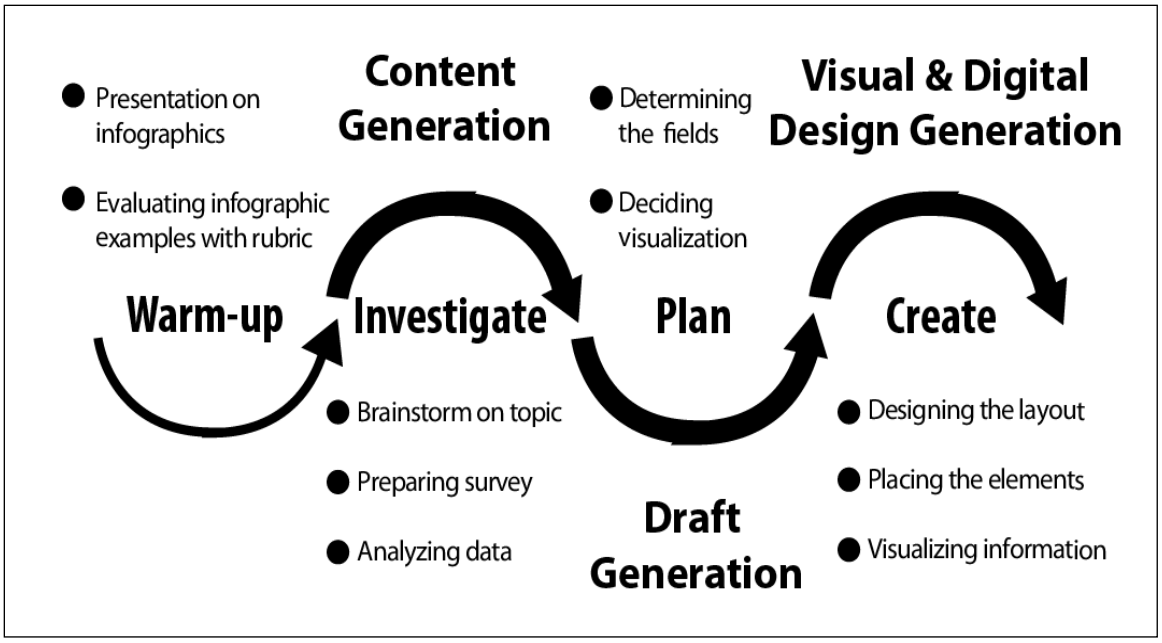


Figure 8. Main structure of process model of creating infographics based on Bridge21 learning model

The teams moved back to the first room to begin generating infographic drafts. The draft generation covers the plan phase of the Bridge21 activity model and began with sharing ideas on what makes an infographic effective. By taking consideration of these ideas, teams determined the fields on their whiteboards with their board markers. They then wrote down main and sub-headings. This step ended with deciding how to visualize information.

Visual and digital design began in the first room by watching short videos on how to use Piktochart. This continued at the computers with their drafts during the create phase of the Bridge21 activity model. The create phase began with deciding the layout of the big picture, and then determining the fields roughly based on information groups they are going to include in their infographics. Just after determining the fields, they placed main and sub-headings, and orientation elements for emphasizing the sub-headings. They worked hard on how to visualize essential information and how to generate accompanying explanations. They completed the infographics by placing identity information. The whole process ended with group presentations, including reflections on their infographics and the design process.

The proposed process model could be visualized in detail for practitioners as in Figure 9.

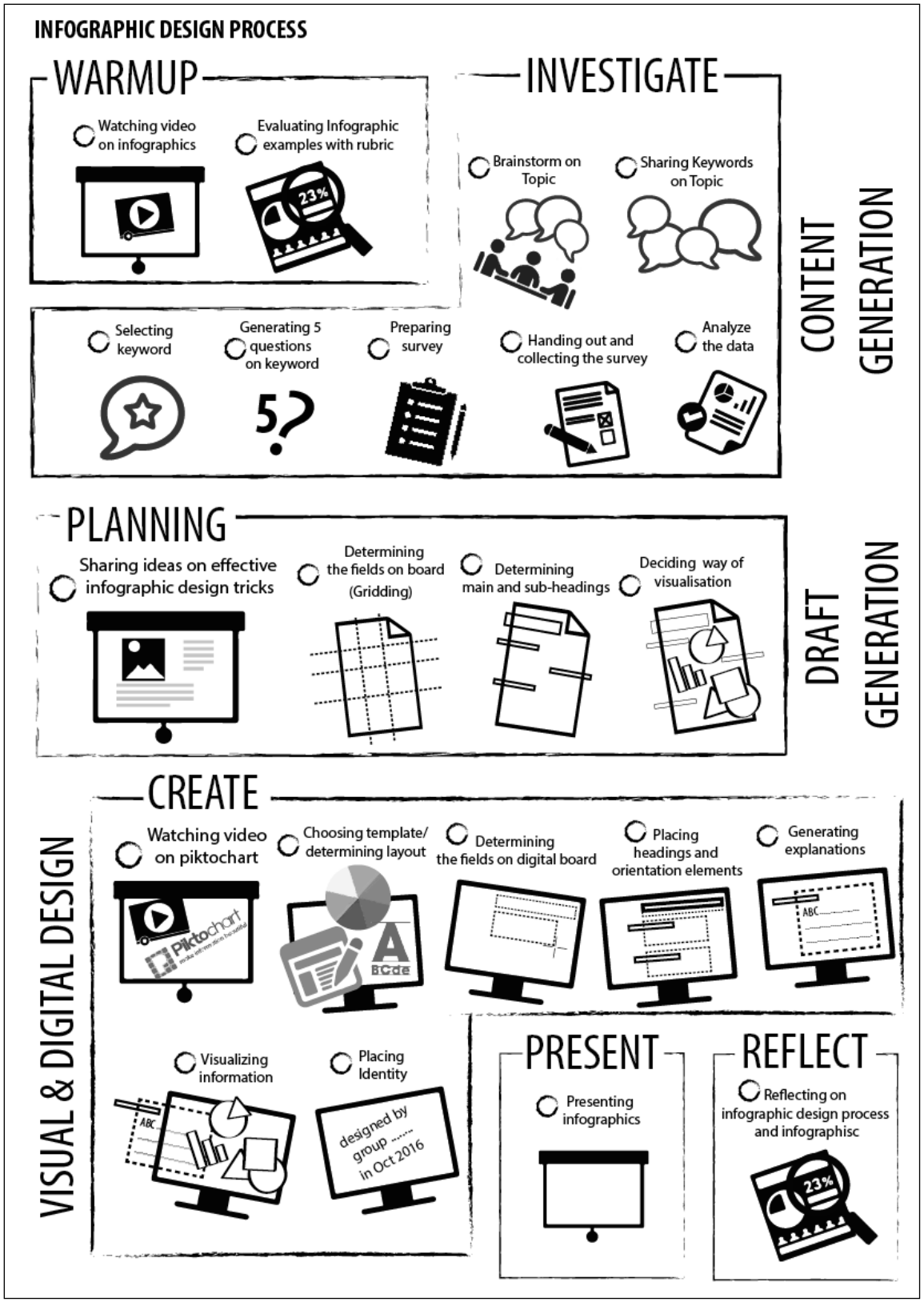


Figure 9. Process model of creating infographics based on Bridge21 activity model

CONCLUSION

The aim of this study was modeling a collaborative process for knowledge visualization, via the creation of infographics. The model was developed by integrating the infographic design model, which handles infographic creation as a learning strategy for individual knowledge visualization (Nuhoğlu Kibar & Akkoyunlu, 2018) into the Bridge21 model for team-based and technology-mediated learning (Lawlor, Conneely, Oldham, Marshall, & Tangney, 2016). The collaborative infographic creation process was improved through three iterative cycles based on the educational design research method (McKenney & Reeves, 2012). This approach comprised of three extended micro cycles of analysis and exploration, design and construction, evaluation and reflection in every cycle.

The improved infographic creation results from the first to third cycle indicated that the proposed infographic creation model could be used for sharing complex knowledge by visualizing the information collaboratively in an infographic form. The process could provide learning situations to construct knowledge collaboratively in a social learning environment, and then present that constructed knowledge visually by using digital design tools.

As it is emphasized by Isenberg et al. (2011), this study combines collaboration and visualization, and proposes a group information processing activity for learning settings through shared use of computer-supported visual representations of data. Beyond previous studies on creating infographics (Abilock & Williams, 2014; Davidson, 2014; Dyjur & Li, 2015; Gallicano, Ekachai, & Freberg, 2014; Matrix & Hodson, 2014; Mendenhall & Summers, 2015; Nuhoğlu-Kibar & Akkoyunlu, 2014, 2015, 2018; Thompson, 2015), this study handles infographic creation as a group knowledge visualization rather than individual learning strategy. Previous studies have shown the infographic design model led to improved outputs from individual learners (Nuhoğlu-Kibar & Akkoyunlu, 2018). This study built on those results to show the effectiveness of the infographic design model for collaborative infographic creation. The generic structure of the Bridge21 activity model (Lawlor et al., 2018), which focuses on team-work, constituted the main spine of the process and proved to be an enabler of collaborative knowledge visualization via the creation of digital infographics.

The investigate, plan and create phases of the Bridge21 learning model (Lawlor et al., 2018) aligned respectively with the content generation, draft generation, and visual and digital design generation phases of infographic design model (Nuhoğlu Kibar & Akkoyunlu, 2018). The identified sub-steps were modified cycle by cycle in order to enhance the collaborative infographic creation process. Adding a short presentation on features of effective infographics, presenting online design tool tutorial videos in the create phase instead of the planning phase, and delivering collaboration plans, were the main modifications. As in previous studies (Kos & Sims, 2014; Matrix & Hodson, 2014), learners had difficulty in writing concise descriptions during the content and draft generation phases. Infographic creation was suggested as an original way for refining writing (Gallicano et al. 2014; Mendenhall & Summers, 2015) and writing was emphasized as an important enabler of creating effective infographics at the same time (Abilock & Williams, 2014). In order to support learners in terms of writing descriptions for generating content, and planning their drafts, instruction on how to use the online design tool was moved from the planning phase to the create phase for not to draw their attention from content to online design tool. A "main description" item was added to the rubric to emphasize the importance of this element. On the second cycle, the addition of a short presentation on how to create effective infographics, including several infographic examples, supported the visual design generation phase. This reinforced previous work that highlighted the importance of analyzing infographics before creating one's own (Davidson, 2014; Kos & Sims 2014). On the third cycle, delivering a collaboration plan through the team leaders enabled them to use time effectively and made every member active through the whole process.

In order to implement this process model effectively, short road maps could be prepared and attached to the collaboration plan and given to team leaders. This could reduce the apprehension around visual design generation. For an implementation infographic creation without time limita-

tions, pushing the teams to create their own icons as a pre-practice would improve their visualization skills. At least a quick presentation or pre-practice on splitting visuals into simple shapes would be a good start in this area. In addition to practice with icons, analyzing infographic examples in terms of their colours by marking and matching and generating a colour palette from those examples could be suggested to raise results on colour effect, visibility of information and redirection.

This study focused on infographic creation as a way of collaborative visualization and will stand out because it proposes a step-by-step generic process model, which was examined through iterative evaluation cycles. An observed rise in gathered infographic results based on the infographic design rubric strengthens the feasibility of the process model. Gathered observations during implementations enhanced the infographic creation process, which especially focused on determining the complicating features of the process design. Observing the students' work was significant in improving the process in terms of collaborative structure. These observations highlighted the importance of a collaboration plan between learners who are collaborating in this learning medium. Being generic, this model could also constitute a structure for future collaborative visualization learning activities. Apart from creating infographics, various visualization methods could be implemented based on this process model by modifying or adding new steps. This model could be transformed and implemented, which would support deep investigation of a topic in order to create and present group knowledge in a visual and digital form beyond infographics.

This study was conducted in a learning environment in which learners shared the same physical space and technologies. The proposed collaborative infographic creation process could be taken as a basis and transformed for online learning settings, which may support interaction in online learning environments by enhancing collaborative knowledge creation. From this point of view, a system could be developed based on the proposed process to provide learners with a road map for collaborative visualization and direct them throughout the process.

Infographics could be designed and used to scaffold the learning process through various forms, such as sharing a course or an advance organizer for recalling prior knowledge. They could serve as explanatory visuals for exposing complex information, exploratory visuals for arousing curiosity and directing learners to research, extended visual summaries for mapping the big picture of the complex content, and evaluation tools to support the learner during assessment process with visual aids. Applications could be developed and also integrated into web-based learning platforms, which would enable teachers to create infographics in those various forms. In order to enhance the effect of infographic creation, a learner generated process needs to be especially focused on applications that enable interactivity between learners. Moreover, enabling learners to create together and providing them with a digital infographics online global library will help create a link between previously created infographics and the one they are creating.

This process model was refined through three implementations conducted in the Bridge21 learning space. This is a purpose built collaborative learning environment and each cycle of the study took place on day three of a four-day program. The students were in a different environment to their usual school classrooms and were working with students from other schools. Students on the Bridge21 program often have a strongly positive disposition and are willing to embrace new challenges enthusiastically. These conditions were enablers of the implementation but can also be indicated as constraints of the research in that they may be difficult to replicate in a traditional school setting.

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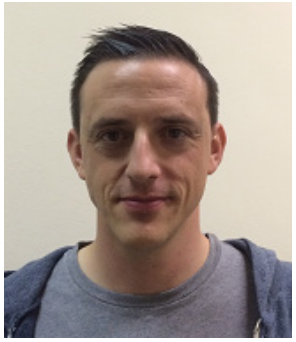

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