Visualizations of Student Time-Use

Amy Rae Fox (amyraefox@gmail.com)
Department of Psychology, California State University – Chico

Erica de Vries (Erica.deVries@upmf-grenoble.fr)
Laurent Lima (Laurent.Lima@upmf-grenoble.fr)
Laboratory of Educational Sciences, Univ. Grenoble Alpes
1251, avenue Centrale, Domaine Universitaire BP 47, F-38040 Grenoble, cedex 9, France

Abstract

How does one visually represent the use of time, when it is a non-visual experience? We asked 25 undergraduates at a public French university to generate representations of their time-use along four components: sequence, duration, timing, and frequency. The resulting use of space and form was analyzed by way of an iteratively developed coding scheme. We discuss the findings and their implications for further study.

Keywords: external representation; diagrams; visualization; time-use; coding scheme

Introduction

How students utilize their time has important implications for their academic and professional success (Fernex, Lima, & de Vries, 2014). Time-use refers to the way humans allocate time to the performance of activities. There are four components that can be derived from time-use data: sequence, duration, timing, and frequency. Sequence refers to the temporal order of activities. Duration refers to the quantity of time spent on a given activity. Timing locates an activity in the context of the culturally prescribed use of clocks and calendars, and frequency refers to the number of times an activity occurs within a specified interval.

The visualization of time-use data, i.e. the representation of these temporal components in a two-dimensional plane, offers numerous practical applications, from event planning, to resource allocation, to detecting patterns in human behavior. It also presents a substantial challenge, as temporal phenomena are not strictly visual and therefore cannot be visually compared to their representations. Duval (2005, 2006) suggests that indeed a *juxtaposition* of an object and its representations, such as the one in Kosuth's conceptual art piece "One and Three Chairs[1]", is necessary in order to accomplish such a comparison.

When speaking about time in everyday language, we routinely employ metaphor (Lakoff & Johnson, 1980), such as in: "The deadline is sneaking up on me, but my manuscript is ahead of schedule." We use metaphor and analogy to create correspondence between unfamiliar (abstract or invisible) and familiar (more concrete) concepts. Similarly, these mappings can be applied in visual forms: graphical metaphors, constructed to convey meaning.

Space and Time as Representational Media

Space and time structure our everyday experience. We think of these as entities to be represented, i.e. as a domain, more than as entities that themselves may represent, i.e. as a medium. Yet, the advantages of space for representation, particularly the two-dimensional plane of a page or screen, have been extensively exploited, researched and documented (Bertin, 1983/1967; Tufte, 2001). It is no coincidence that these discussions originated primarily in geography extensively relying on spatial representations of space. The observation that space is best represented in a spatial medium is common place (Larkin & Simon, 1987) and a clear example of intrinsic representation (Palmer, 1978). A representation is intrinsic when the properties of the representational medium match those of the represented domain, for example, when a transitive relation in a domain, such as "larger than", is represented by a transitive relation in a graphical medium, such as "taller than" depicted by bars in a histogram.

In contrast to space, time is less frequently considered a representational medium. Bertin (1983/1967), however, noted how time does serve as a representational medium in language, cf. in speech. Even in written text laid out in on a plane, sequence in terms of the order of letters, syllables, words, and sentences must be preserved in production and in interpretation; otherwise, meaning is lost or changed. Representing time in time is also a case of intrinsic representation. For example, we do not need a clever device to represent sequence in language since the property of order in a domain, such as the sequence of daily activities, matches the order in which the activities are uttered, such as in: "We got up and had breakfast." Much like the argument that visual-spatial representations allow the viewer to simply "read off" (spatial) information (Larkin & Simon, 1987), representations in a auditory-temporal medium allow listeners to simply "listen off" (sequence) information, i.e. that the event of getting up preceded the event of breakfast.

Data collection in time-use research traditionally relies on diaries. If linearity is respected when filling them out, a diary can be considered a representational medium preserving temporal properties akin to a tape-recording,

[1] Kosuth's 1965 work consists of a chair, a photograph of the chair, and an enlarged dictionary definition of the word "chair".

conserving the four components: sequence, duration, timing, and frequency. However, using a spatial medium to represent temporal phenomena is a case of extrinsic representation. A representation is extrinsic when the properties of the medium and the domain do not coincide, such that the properties of the domain must be enforced on the medium in a more or less arbitrary manner (de Vries, 2012; Palmer, 1978). For example, in order to represent sequence in a two-dimensional plane, one needs some artificial device that restores the intrinsic property of linearity. This can be accomplished by a graphical form, such as an arrow, by evoking a domain-specific representational format such as a calendar or diary, or by relying on reading direction as a commonly shared technique for imposing linearity on a two-dimensional visual medium.

This suggests a fundamental asymmetry when using space to represent anything other than space and *a fortiori* time. This domain asymmetry is consistent with empirical findings in cognitive linguistics (Boroditsky, 2000; Casasanto & Boroditsky, 2008), which suggest that individuals may use spatial information when thinking about time, but rarely use temporal information when thinking about space.

Form and Space in Diagrams

Tversky (2011) examines how space and form are used to convey meaning in diagrams. She first identifies the use of space for depicting order, positioning forms (i.e. marks on the page) along horizontal, vertical and central-peripheral planes. She suggests that the "salient dimensions of the world" reinforce these orientations, while certain properties of human vision (notably the acuity of the center of the visual field) serve to ground the latter (Tversky, 2011, p. 509). These axes are not equivalent, however. While both the horizontal and vertical can effectively represent order (e.g. first to last, greatest to least) the center-periphery can only indicate relative importance, as the space of the page extends from the center-outward equally in all directions. Tversky identifies a number of spatial conventions evident in empirical studies of graphic representation. A cross-cultural examination of productions by children revealed a strong relationship between direction of written language and depiction of temporal sequence for both Arabic (right to left) and English (left to right) readers (Tversky, Kugelmass, & Winter, 1991). It seems the horizontal use of space is strongly influenced by the reading direction in literate individuals. While use of the horizontal dimension is flexible, Tversky suggests the vertical dimension is often used to express evaluative concepts with asymmetric values (such as quantity, quality, and strength). Both observations are consistent with our bodily experience of the world, in which we find left-right symmetry in the environment, but must literally overcome the force of gravity to move upward in the vertical direction.

Space exists in multiple dimensions, while form on the other hand, is constructed. Complex forms are constructed by combining simple forms in purposeful configurations. The simplest forms are points and lines, which can be extended, contoured and combined to generate realistic depictions of worldly objects, or more abstract flights of imaginative fancy.

Flexibility in Representation

In response to an instruction to produce representations, participants can do a number of things depending on the affordances of the medium (the two-dimensional plane) and their "catalogue" of available responses. Reachlin (as cited in Lautrey, 2003) coined the term *vicariance* for the ways in which an individual may rely on a number of redundant mechanisms for performing a cognitive task. This flexibility gives the human cognitive system robustness against local impairments, and serves as a basis for individual differences. We think of representation as a vicariant process, where the potential representational formats are determined by the individual's repertoire of available behaviors. In the case of university students (with paper and pencils) we might expect to see:

- *Linguistic and numerical representations:* text, labels, digits, etc. (descriptions)
- *Figurative drawings:* attempted realism (depictions)
- *Standard representations:* histograms, line graphs, pie charts, mind maps, etc.
- *Domain-specific representations:* particular to the domain in which they have evolved (diSessa, 2004).
- *Ad-hoc representations*: inventing a new context-specific representational format rather than using an existing one.

If like Tversky (2011), we consider the process of representation an indicator of underlying thought, then examining the graphic productions of student time-use may help us understanding how students conceptualize this important factor of their academic success. As a first step towards this goal, we explore the variability of representational behavior in a student population. Our analysis is guided by three questions:

(1) How do students use space to represent time-use?
(2) How do students use form to represent time-use?
(3) Which mechanisms form and space are used to represent each component: sequence, timing, duration and frequency?

Method

Participants

Twenty-five (22 female, 3 male) undergraduate Education majors at a public French university participated as a requirement of a graduate studies preparation course. The median age was 23 years.

Materials

A narrative was constructed to prompt students to produce expository productions of their own time-use for a typical week during the academic year. The scenario explicitly called for representation of five components: activity (what), sequence (order), duration (quantity), timing (chronological point in time), and frequency (number of occurrences). The students were given one sheet of A4 paper and instructed to create as many representations as necessary using any graphic conventions desired. The scenario was carefully worded to use only the term "representation" when referring to the output, avoiding a bias in representational formats with words such as: chart, graph, picture, sketch, icon, or text. Students were provided with pens, pencils, highlighters and colored pencils.

Procedure

The students first completed a short demographic survey and were given a sheet of paper containing the narrative and instructions. Students had one hour to read the scenario and complete their representations.

Coding Scheme

The coding scheme was developed using a directed approach (Hsieh & Shannon, 2005). First, categories were defined in response to the research questions, in alignment with the discussion of space and form (Tversky, 2011). The scheme was then applied to a subset of diagrams (n=5). Multiple modifications were made resulting in the addition of two variables and the removal of another. Operational definitions were developed for each variable with values that were exhaustive and mutually exclusive. Separate coding schemes were developed for Space (Table 1), Form (Table 2), and Primary Mechanisms (Table 3).

Table 1: Coding Scheme for Use of Space.

#	Variable	Values (select one)
S1	Gestalt Use of Space	1 = Linear 2 = Circular
S2	(Linear) Horizontal	0 = None 1 = Left → Right 2 = Both 3 = Right → Left
S3	(Linear) Vertical	0 = None 1 = Top → Bottom 2 = Both 3 = Bottom → Top
S4	(Circular) Circumferential	0 = None 1 = Clockwise 2 = Both 3 = Counterclockwise
S5	(Circular) Radial	0 = None 1 = Periphery → Center 2 = Both 3 = Center → Periphery
S6	Location of Origin	0 = Top Left 1 = Bottom Left 2 = Bottom Right 3 = Top Right 5 = Center

The first variable concerned the Gestalt use of space (S1) with the values linear or circular. Linear representations appeared to follow a path whose end did not return to its beginning, while circular representations resembled a curved path with no start or finish. The dimensions of the page were defined relative to the student's frame of reference. The horizontal and vertical orientations corresponded (respectively) to the long and short sides of a sheet of paper, and the center-periphery to the middle and boundaries of the page. Variables (S2-S5) were assigned to evaluate the direction of information flow: horizontal, vertical, clockwise/counterclockwise, and center-periphery. Raters considered the question: in what direction does the author intend you to follow the information? In evaluating this task, it was critical to consider the whole representation as the unit of analysis in order to code the flow of information, rather than the direction of text, which would skew the results in favor of left to right, top to bottom and clockwise values. Finally, we evaluated the point of origin in each representation (S6). The start of the day was defined as first activity beginning after 12:00 AM.

A pragmatic approach was followed when analyzing form, thus accommodating a wide range of artistic abilities. Forms that were used consistently throughout a drawing were identified as indicative of an intentional choice by the student. Of particular interest was the students' use of text versus numbers versus drawings. To examine these choices two rules were adopted. (1) A limited number of textual characters were considered numeric in the coding scheme, when their purpose was clearly to label a numeric value. These include: h/hr m/min, s/sec, x/times/#, am, and pm. (2) Text within a diagram was considered as part of a drawing and text accompanying a diagram was considered text.

Table 2: Coding Scheme for Use of Form.

#	Variable	Definition
F1	Text	Alphabetic symbols in French/English
F2	Number	Digits and text units of measure
F3	Drawing	Depictive graphical representations
F4	Arrow	Line with a directional end
F5	Color	More than one color present

Finally, raters identified each component of time-use (M1-M5), and indicated which of the spatial and form mechanisms were employed in their representation.

Table 3: Coding Scheme for Primary Mechanisms.

#	Variable	Values (all that apply)
M1	Activity	
M2	Duration	Size, Position
M3	Timing	Text, Number, Drawing,
M4	Sequence	Arrow, Color, Other
M5	Frequency	

The resulting scheme was applied to the diagrams by three psychology graduate students who coded the entire sample. After every five diagrams, the raters paused to discuss their evaluations, following the constant comparison method (Glasner & Strauss, 1967 as cited in (Marsh & White, 2006). In the case of discrepancies, each rater explained their interpretation of the coding scheme, after which raters could revise or maintain their assessment. The final scheme reflects a response to the both the research questions and the evidence present in the sample. Coding results for the entire sample were evaluated for inter-rater reliability, with positive outcomes. Krippendorff's alpha was selected as the most appropriate measure of reliability for nominal variables assessed by more than two coders (Hayes & Krippendorff, 2007). For use of space (S1-S6) α = 0.87, use of form (F1-F5) α = 1.00 and primary mechanisms (M1-M5) α = 0.97, all exceeding the recommended threshold of $\alpha \geq 0.80$. Finally, a combined coding result was constructed from the individual results based on the majority rating.

Results

Use of Space

The use of space in the diagrams (n=25) was consistent with our expectations based on reading direction in French. 21 diagrams were characterized as linear and four as circular. Nearly all of the students (22) depicted the start of the day in the upper left corner of the page. Of the remaining three, two were circular representations placing the start of the day at the 12:00 position of a clock, and one was linear, starting in the lower left corner.

Linear Representations 19 of the 21 linear diagrams utilized both horizontal and vertical axes, while the remaining two diagrams utilized only the horizontal axis. 16 of the diagrams adopted a left-to-right orientation, while four alternated directions in a snake-like pattern. Figure 1 is a prototypical example of linear representation, with the origin in the top left corner of the page. In these cases, the reader scans the diagram from left to right, jumping at the end of horizontal space, consistent with reading behavior.

Snake Representations Four diagrams avoided the end of line scanning effect by alternating direction at the end of each line (Figure 2). We dubbed these "snakes", as the information appeared to slither across the page. In each case, the students started in the upper left corner and depicted first left-to-right and then right-to-left. In each case a form, either line or arrow, accompanied the transition to indicate the change in direction. We contrast this with Figure 1 in which the student assumes the viewer will skip to the next line and continue reading left to right, without the need to provide a formal indicator of direction.

Circular Representations Of the four circular diagrams, three presented information in the clockwise direction as shown in Figure 3. There was minimal use of the radial orientation, with only two diagrams depicting flow from the periphery of the circles toward the center in a spiral fashion.

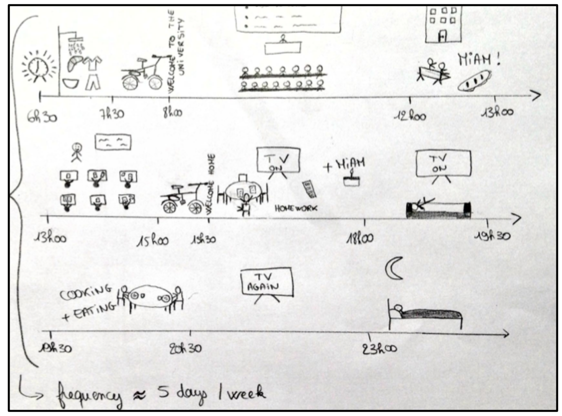

Figure 1: A prototypical linear representation.

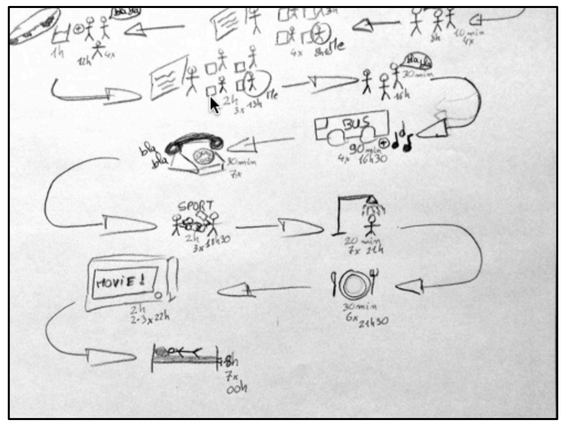

Figure 2: A snake representation.

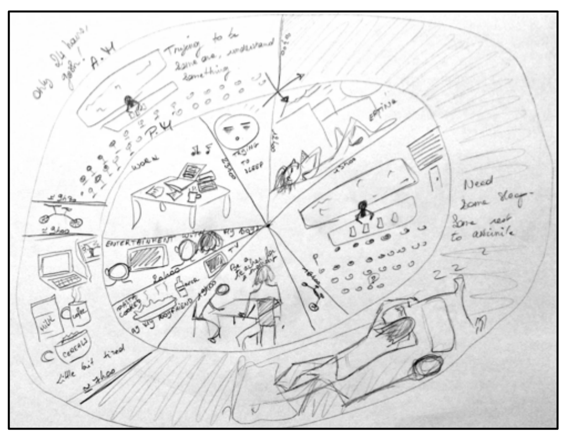

Figure 3: A circular representation.

Use of Form

The use of form in the sample varied greatly, suggesting the scenario was effective in motivating students without biasing their use of visual form. While developing the coding scheme, raters found few instances of meaningful glyphs (Tversky, 2011) such as dots, lines, and boxes, and they were therefore removed from the analysis. *Arrows* were the noticeable exception, found in 21 diagrams, and used to orient the viewer from "earlier" to "later" activities. *Number* was the most prevalent form in the sample, found in 23 of the 25 diagrams, followed by *text* with 21. 19 individuals included depictive drawings, while only 13 utilized more than one color. Figures 4 - 6 exemplify the range of forms in the drawings from highly depictive to highly descriptive. As evident in these examples, the use of text vs. depictive drawings to describe activities fell on a continuum. There were no examples of prevalent but poorly executed drawings.

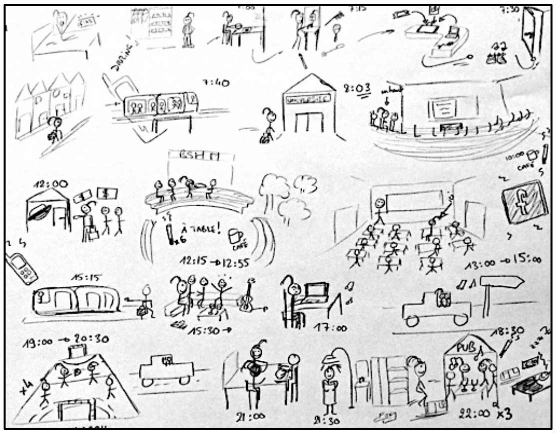

Figure 4: A depictive representation.

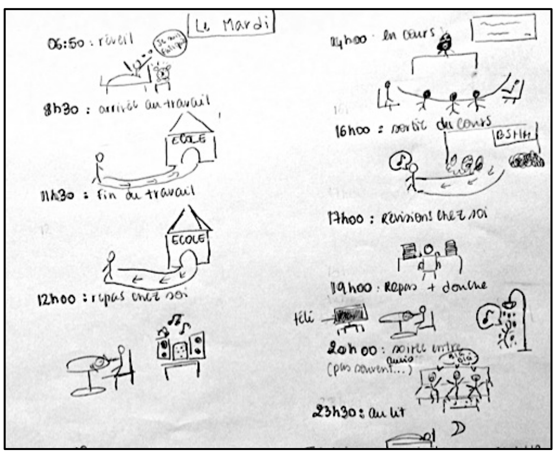

Figure 5: A balanced representation.

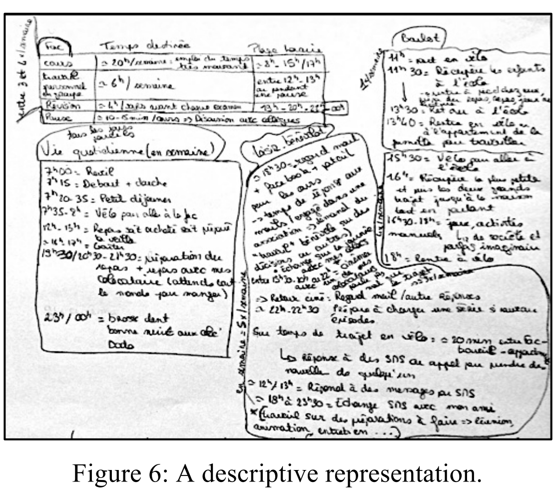

Figure 6: A descriptive representation.

Primary Mechanisms

Table 4 describes the percentage of diagrams that represented each component of time-use, as well as the number of diagrams utilizing each mechanism in the coding scheme. Note that any component of time-use (such as sequence) could be represented by multiple mechanisms, thus each cell has a maximum value of (n=25).

Table 4: Frequency (# of diagrams) of Time-Use Components

Mechanism	Sequence	Timing	Duration	Frequency
% Inclusion	100 %	96%	54%	46%
Position	25	2	1	2
Size			4	
Text				
Number	2	21	9	6
Drawing		2	1	1
Arrow	15			
Color		2		2

Only four individuals effectively represented all four components of time-use. Frequency was most commonly neglected, followed by duration, then timing. Sequence was always indicated by position, in many cases with the addition of arrows, while timing was almost exclusively represented by number. Two imaginative illustrations also utilized position to indicate timing by placing drawings around the corresponding positions of a clock face to indicate the time of day they began. Duration was often absent from the drawings, but when it was present, it was indicated by number. Two novel illustrations also utilized color to differentiate categories of activities.

Discussion

We found that students were capable of producing a wide range of representations using a variety of spatial principles and visual forms. Our analysis revealed that students utilized all three methods for extrinsically representing time in a two-dimensional visual medium: arrows, evoking domain-specific representations (diaries & calendars) and reliance on reading direction.

Regarding the use of space, we observed a preference for linear patterns orientated in accordance with reading direction. Very few students used circular patterns to indicate cyclical phenomena. Tversky (2011) made a similar observation, noting that students were reluctant to produce circular diagrams even when asked to model cycles and processes. She suggests that linear thinking is easier than cyclical, and that students may prefer to consider a simple forward progression of time. Another explanation is the influence of cultural artifacts on the choice of representational format. The linear flow of information in the diagrams was evocative of weekly calendars and daily agendas. This suggests that the graphics students utilize for planning may influence their choice of representational format.

Regarding form, text and figurative drawings were used along a continuum to represent activities, while number was used to describe timing, frequency and duration. Arrows were used exclusively to enforce linearity, directing the viewer's attention to the forward flow of time.

Of greatest interest were the students' choices for representing the components of time-use. Although the instructions explicitly allowed for the creation of multiple representations, all 25 students attempted to create a single integrated diagram. Alternatively, students could have created different representations for each component. Only two out of the five types of representations of the a priori catalogue were observed: linguistic/numerical and figurative representations. Standard representations such as pie or bar charts were not exploited, despite their efficiency in communicating quantities, such as duration. The study featured a homogeneous sample of education majors, to whom these formats were either not familiar, or not considered suitable for the communicative purpose. Future work may include students in science and engineering in order to explore variance in representational preference as a function of prior knowledge. While no student constructed a complete domain-specific representation (such as a diary or calendar), several utilized space in a fashion consistent with those representations. The remaining students' productions demonstrate a preference for complex, integrated diagrams, reflecting an attempt at simultaneously inventing a representation and a representational format (ad-hoc context-specific representation). An alternative explanation for the observed preference for complexity is that the students might place a high value on informational efficiency. To examine this hypothesis, we suggest refining the communicative task from one of "informing" to differentiated tasks for planning, problem solving and exposition. In addition to revealing sources of variation, a more strictly defined communicative purpose might allow one to more reliably infer about the underlying conceptual structure suggested by an individual's graphic production.

Overall, our analysis demonstrated noticeable trends in student representations of time-use, consistent with the existing literature on representation of temporal order and representational forms. The act of generating representations also prompted student reflection. Having demonstrated the utility of the coding scheme, we suggest that future work seeking to understand how students conceptualize their time-use proceed by evaluating the content of productions in conjunction with pedagogical activities on time planning and evaluation. Constructing and analyzing representations of time-use may help students improve their understanding and take control of this important factor of their academic success.

Acknowledgments

The authors gratefully acknowledge the Atlantis Grant Program and the U.S. Department of Education for support of the International Cognitive Visualization program, and partial support of the first author's research.

References

Bertin, J. (1983). *Semiology of Graphics: Diagrams, Networks, Maps*. Madison, WI: University of Wisconsin Press. Original published in 1967.

Boroditsky, L. (2000). Metaphoric structuring: understanding time through spatial metaphors. *Cognition*, *75*, 1-28.

Casasanto, D. & Boroditsky, L. (2008). Time in the mind: using space to think about time. *Cognition*, *106*, 579-593.

De Vries, E. (2012). Learning with External Representations. *Encyclopedia of the Sciences of Learning*, 2016-2019.

diSessa, A. (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction*, *22*, 37-41.

Duval, R. (2005). Transformations de représentations sémiotiques et démarches de pensée en mathématiques. In J.-C. Rauscher (Ed.), *Actes du XXXIIe Colloque COPIRELEM* (pp. 67-89). Strasbourg: IREM.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics*, *61*, 103-131.

Fernex, A., Lima, L. & de Vries, E. (2014). Exploring time allocation for academic activities by university students in France. *Higher Education*, 1-22.

Hayes, A. F. & Krippendorff, K. (2007). Answering the Call for a Standard Reliability Measure for Coding Data. *Communication Methods and Measures*, *1*, 77-89.

Hsieh, H.-F. & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*, 1277-1288.

Lakoff, G. & Johnson, M. (1980). *Metaphors We Live By*. Chigaco: University of Chicago Press.

Larkin, J. & Simon, H. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, *99*, 65-99.

Lautrey, J. (2003). A pluralistic approach to cognitive differentiation and development. In R. J. Sternberg, J. Lautrey, & T. I. Lubard (Eds.), *Models of intelligence: International perspectives* (pp. 117-131). Washington, DC: APA Press.

Marsh, E., & White, M. (2006). Content analysis: A flexible methodology. *Library Trends*, *55*, 22-45.

Palmer, S. E. (1978). Fundamental Aspects of Cognitive Representation. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and Categorization* (pp. 259-302). Hillsdale, NJ: Erlbaum.

Tufte, E. (2001). *Visual Display of Quantitative Information* Cheshire, CT: Graphics Paper Press LLC.

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, *3*, 499-535.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515-557.