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An investigation of the impact of a social constructivist teaching approach, based on trigger questions, through measures of mental workload and efficiency

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Abstract: Social constructivism is grounded on the construction of information with a focus on collaborative learning through social interactions. However, it tends to ignore the human mental architecture, pillar of cognitivism. A characteristic of cognitivism is that instructional designs built upon it are generally explicit, contrarily to constructivism. This position paper proposes a novel learning task that is aimed at combining both the approaches through the use of trigger questions in a collaborative activity executed after a traditional delivery of instructions. To evaluate this new task, a metric of efficiency based upon a measure of mental workload and a measure of performance is proposed. The former measure is taken from Ergonomics, and two well know subjective self-reporting mental workload assessment techniques are envisioned. The latter measure is taken from an objective quantitative assessment of the performance of learners employing concept maps.

1 Introduction

The theoretical premises of this position paper relate cognitivist and social constructivist approaches to learning. The former is built upon the human mental architecture and is grounded in the transferral of information from short to long term memory, supporting in practice learning. From the cognitivist point of view, receiving explicit instructions is ‘condicio sine qua non’ the transfer of information can occur. The latter is grounded in the construction of information with a focus on the collaborative nature of learning which is a product of social interactions. However, as Sweller (2009) pointed out, constructivism in general ignores the human mental architecture. As a consequence, constructivism can not lead to instructional designs aligned to the way humans learn, so they are set to fail. An important issue of constructivism is the lack of explicit instructional designs (Kirschner et al., 2006). The research question being proposed in this paper is: *To what extent can a social constructivist activity improve the efficiency of a traditional cognitivist activity when added to it?*' To answer this, an existing metric of teaching efficiency proposed by Paas and Van Merriënboer (1993) is adopted. This is based upon two other measures: the cognitive load experienced by learners and their performance. However, both these two measures are hard to be precisely and objectively quantified. An important theory in educational psychology, based upon the construct of cognitive load, is the Cognitive Load Theory (CLT). This is a theoretical framework that provides guidelines to assist instructors in the presentation of information by incorporating explicit instructional design to foster the learners' activities and optimise their intellectual performance (Sweller et al., 1998). CLT argues that instructional designs can generate three types of load: the extraneous, the intrinsic and the germane load. The extraneous load corresponds to the way by which the information is presented. The intrinsic load refers to the level of difficulty of an underlying learning task while the germane load relates to the mental resources used to complete the learning task by creating schemata of knowledge in working memory

(Sweller, 2010). Regrettably, despite decades of research endeavour, no empirical measures of the three types of load have emerged. As a consequence, the theory has been criticised and believed not to be scientific in nature as it does not allow empirical investigations (Gerjets et al., 2009; De Jong, 2010). Contrarily, the situation in Ergonomics is favourable, and an entire field of research is devoted to the development of measures of Mental Workload (MWL), a psychological construct strictly connected to cognitive load. According to Wickens (2012), MWL is the amount of the mental resources that humans need to carry on a task. This is connected to the human working memory which is limited in its capacity so, to get an optimal performance, it is necessary not to exceed its limits. If this occurs, the mental resources are no longer sufficient to complete a task causing a situation of overload (Paivio, 1986; Baddeley, 1998). In relation to learning, an optimal level of mental workload facilitates the learning process, whereas a high level (overload) or a low level (underload), hampers the learning phase (Longo, 2016). Although a robust and generally applicable measure of MWL still has to emerge, a number of uni-dimensional and multi-dimensional measures have been conceptualised, applied and validated. Examples include the Nasa Task Load Index and the Workload Profile (WP), well known multidimensional assessment techniques. Similarly to mental workload, objective performance of learners is hard to quantify. Assessing their performance after a learning activity is far from being easy. However, a number of assessment strategies have been proposed. One of these is based on conceptual maps, useful tools that display a concept's component visualising their relationships and organising the related thoughts. This type of maps can be objective and meaningful assessment tools to evaluate an instructional design in the classroom. They are expected to be effective to identify both valid and invalid ideas grasped by learners and they can provide quantitative information about the performance achieved by a learner (Novak and Cañas, 2008). Having quantitative measures of mental workload and objective performance, through an existing measure of efficiency, it is now possible to answer the research question set above. The missing element is the formation of a novel learning task that combines the cognitivist and social constructivist approaches. The proposal of this position paper is to make use of traditional explicit instructions methods followed by a collaborative activity based upon trigger questions. These questions are aimed to exercise the cognitives abilities of a learner and to develop a higher level of thinking (Lipman, 2003).

The reminder of this paper is organised as it follows. Section 2 discusses the theoretical background of the research with an overview of cognitivist and social constructivist approaches to teaching and learning discussing their limitations. The human mental architecture, in the context of Cognitive Load Theory (CLT), is subsequently described emphasising its drawbacks. A focus on human Mental Workload (MWL), its measurement techniques and measures follows. A description of conceptual maps and a marking scheme for their objective evaluation is presented. Eventually, the origins of trigger questions and their functioning is described. With these notions, section 3 proposes the design of a noverl primary research experiment while section 4 emphasises the expected contribution to the body of knowledge.

2 Related work

2.1 The cognitivist paradigm

The traditional cognitivist approach to teaching is focused on the transmission of information. It stresses the acquisition of knowledge and considers the internal mental structure of humans. Its focus is on the conceptualisation of learning processes. Cognitive theories address how information is received, organised, stored and retrieved by the mind. 'Learning is concerned not so much with what learners do but with what they know and how they come to acquire it' (Jonassen, 1991). The goal of Cognitivism is to use appropriate learning strategies to relate new knowledge to the prior knowledge. According to Schunk (1996), 'Transfer is a function of how information is stored in memory'. The emphasis is on the role of practice with corrective feedback. Transfer occurs when a learner is able to apply knowledge in different circumstances. To support this, instructional designers usually adopt two different techniques: simplification and standardisation. The transfer occurs when irrelevant information is eliminated, when simplification and standardisation techniques facilitate the knowledge transfer to achieve effectiveness and efficiency. During this transfer phase, knowledge is analysed, decomposed, and simplified into schemata. A schema synthesises the functions required to carry out a task (Mayer, 2002).

2.2 The social constructivist paradigm

Vygotsky (1986), Dewey (2004), Lipman (2003) consider learning strictly being related to the social context. The individualistic ideal of autonomy to teaching and learning is characterised by self-sufficiency and independence. From this point of view, dependency, inter subjectivity, and community are seen as opposed to autonomy and maturity. Thus, self-sufficiency and independence are seen as virtuous, while dependency and interconnectedness with others are considered weaknesses (Bleazby, 2006). Under this assumption, it is believed that the exacerbation of the individualistic ideas of autonomy could create competitive behaviours that could hamper instead of facilitating the learning phase (Bleazby, 2006). Social interaction is considered as a potential solution for facilitating the learning phase and to fill in the gap of different levels of prior knowledge of learners.

The Deweyian and Vigotskyian notion of autonomy is incorporated and developed in the pedagogical approach proposed by Lipman (2003). 'In order to think for oneself, one must be a member of a community'. In a community, the social interaction internalises the functions and the processes of the interaction. Therefore, the participants become intrapsychological functions: the learners create, define and redefine the meanings by themselves after having participated in a dialog with the others (Vygotsky, 1986). This notion is strictly connected to the notion of Community of Inquiry proposed by Peirce (1877). Here, the focus is on the formation of knowledge through a process of scientific inquiry. The Community of Inquiry can be defined as a group of people interacting in a social context who investigate the conceptual limits of a problematic concept through the use of dialog. Here, 'Dialog' is not a conversation nor a discussion. A conversation is a spontaneous exchange and sharing of ideas and information. A discussion is a conversation where participants explain their own ideas trying to persuade the others. It is a competitive dialectical exchange of ideas that converges to the extrapolation of the correct one, emphasising a winner. Instead a dialog focuses on group thinking, processing the information in order to expand individual and group knowledge and to extend understanding (Bleazby, 2006).

In line with the definition of dialog, a pedagogical framework grounded in the 'Philosophy for Children' proposed by Mathew Lipman exists (the project NORIA) (Sátiro, 2006). It proposes a set of questions aimed to exercise the cognitives abilities of a learner and to develop a higher level of thinking. Lipman (2003) presents a model of reasoning which is considered to be a genuine and important aspect of any instructive process: the complex thinking. It is an educational process composed by three dimensions: critical, creative and caring thinking. The critical thinking is focused on the formulation of judgements and it is governed by the criteria of logic, it is self-correcting and sensitive to the context. The creative thinking tends towards the formulation of judgements too but these are strictly related to the context. Additionally, it is governed by the context, it is self-transcendent and it is sensitive to criteria but not governed by them. The caring thinking is aimed at the development of practice regarding substantial and procedural reflection related to the resolution of some problem. It is sensitive to the context and it requires metacognitive process of thinking to formulate and orient practical judgments. The development of complex thinking occurs in the Community of Inquiry, a process of discovery learning which is focused on generating and answering philosophical questions on logic (critical thinking), aesthetic (creative thinking) and ethic (caring thinking).

2.3 The Human mental architecture and the Cognitive load theory

The human mental structure is believed to be composed by two parts: short and long term memory (Atkinson and Shiffrin, 1968). The former memory processes incoming information, while the latter stores relevant information transforming it as acquired knowledge (Baddeley, 1998; Miller, 1956). Under the assumptions of the human mental architecture framework, learning takes place by transferring pieces of information from working memory, conscious and limited, to long term memory, unconscious and unlimited (Atkinson and Shiffrin, 1968; Baddeley, 1998). This assumption is at the core of the Cognitive load theory (CLT) (Sweller et al., 1998). According to CLT, in the learning phase, the transfer of information occurs by generating schemata of knowledge. Here, schemata are automatic functions created after several application of some concept related to some task (Sweller et al., 1998). The creation of schemata reduces the working memory load because of their capacity to hold undefined amount of information. According to the Schema Theory, knowledge is stored in long term memory in the form of schema. A schema categorises elements of information according to the manner in which they will be used (Sweller et al., 1998). To construct a schema means to relate different kinds of information from a lower to a higher level of complexity and hold them as a single unity understandable as a single chunk of information. In summary, the construction of schemata occurs in working memory while their permanent storage occurs in long term memory. Cognitive Load Theory is aimed at providing guidelines to design instructional material to reduce the cognitive load of learners and at expanding their working memory limits, facilitating the transfer between short and long memory. The research conducted in the last 3 decades by Sweller and his colleagues brought to the definition of three types of load: intrinsic, extraneous and germane load. The intrinsic load refers to numbers of elements that must be processed simultaneously in working memory for schema construction and their interactions (defined as element interactivity). Extraneous load is the unnecessary cognitive load and it influences by the way instructional material has been designed. Germane load is the effective cognitive load which is the result of beneficial cognitive processes such as abstractions and elaboration (the construction of schemata) that are promoted by a clear design of the instruction (Gerjets and Scheiter, 2003). The three types of load were initially thought to be additive: the total cognitive load experienced by a subject during a task correspond to the sum of the three different types of load. Reducing extraneous load and improving germane load by developing schema construction and automation should be the main goal of the discipline of instructional design.

After several critiques related to the theoretical development of CLT, as in Schnotz and Kürschner (2007), Gerjets et al. (2009) and De Jong (2010) and after several failed attempts to find a generally applicable measurement of the three different types of load, CLT has been re-conceptualised using the notion of element interactivity, as previously discussed. If initially the degree of element Interactivity underlined the intrinsic load, now it also underlies the extraneous load (Sweller, 2010). This re-conceptualisation brought to a new definition of extraneous load itself that now refers to the degree of interactivity of the elements of instructional material used for teaching activities. In other words, if an instructional design enhances the degree of element interactivity during problem solving, the load can be considered as extraneous. In contrast to the previous definition of extraneous load, which focused on hampering the schema contribution and automation, now extraneous load is defined as the degree of element interactivity as well as the germane load. This is because, indirectly, the degree of element interactivity underlies germane load due to the fact that the latter refers to the working memory resources devoted to manage the interaction of elements. Germane load is no longer an independent source of load. It is now a function of those working memory resources that need to deal with the interaction of the elements of the instructional material being presented. Intrinsic load depends on the characteristic of the material, while extraneous load now depends on the characteristic of the instructional material, on the characteristic of instructional design and on the prior knowledge of the learners. Additionally, germane load now refers only to the characteristics of the learner: the resources of working memory allocated to deal with the intrinsic load. According to this reconceptualisation, the logical foundation of CLT have become more stable, and germane load is complementary to extraneous load without creating logical and empirical contradictions.

In summary, to the best of our understanding, the main theoretical contradiction before the reconceptualisation of CLT was that germane and extraneous loads were additive Sweller et al. (1998) and at the same time complementary. This means that, if extraneous load decreases, while keeping the intrinsic load constant, then germane load should increase. 'However, if germane load can compensate extraneous load, why does total load change? It should remain constant but does not' (Sweller, 2010). After the reconceptualisation of CLT by Sweller (2010), if intrinsic load remains constant but extraneous load changes, the total cognitive load changes as well because more or less working memory resources are devoted to deal with the degree of element interactivity Sweller (2010). Additionally, germane load is a function of working memory dealing with the degree of element interactivity. At a given level of knowledge and expertise, intrinsic load cannot be altered without changing the content of the material being learnt. Rather, extraneous load can be altered by changing the instructional procedures and germane load is a function of the resources of the working memory dealing with the processing of the interactions of instructional elements of an underlying learning task. Germane load is no longer independent because it depends on the instructional design and the complexity of the underlying learning task (Sweller, 2010). Despite the evolution of the theory over the years, reliable measurement of the three different types of load is still the main challenge regarding the theoretical and the scientific value of CLT (Paas et al., 2003).

2.4 Mental workload

Although the field of educational psychology is struggling to find ways of measuring mental workload of learning tasks, there is an entire field within Ergonomics devoted to the design, development and validation of reliable measures of mental workload (Longo and Leva, 2017). In the last 50 years of research, different definitions of mental workload (MWL) have emerged in the literature. According to Wickens (1979) '..., the concept of operator workload is defined in terms of the human's limited processing resources'. His Multiple Resource Theory (MRT) states that humans have a limited set of resources available for mental processes (Wickens, 1984). These resources correspond to an available amount of energy that is used for a variety of mental procedures. This shared pool of resources are allocated across different stages related to the tasks, their use depends on the modalities of the task and on the process required to carry out this task. Cognitive resources are restricted and a supply and demand problem occurs when a person performs two or more tasks that require the same resource. Excess workload, caused by a task using the same resource, can create problems and result in errors or lower task performance. When workload increases it does not mean that performance always decreases: performance can be affected by workload being too high or too low (Nachreiner, 1995). A high level of mental workload can be related with a high level of focus on the task whereas a low level might means no attention or no mental resources allocated to a task. Wicken's definition implicitly means that mental workload should be optimal to increase the performance during tasks. In general, MWL is not a linear concept (Longo, 2015; Rizzo et al., 2016) but it can be intuitively defined as the volume of cognitive work necessary for an individual to accomplish a task over time. It is not 'an elementary property, rather it emerges from the interaction between the requirements of a task, the circumstances under which it is performed and the skills, behaviours and perceptions of the operator' (Hart, 2006). However, this is only a practical definition, as many other factors influence mental workload (Longo and Barrett, 2010; Longo, 2014).

2.4.1 Mental workload measurement techniques

Different techniques have been proposed in the Eductiton to measure mental workload (cognitive load). This can be clustered, in two main groups: subjective and objective measures (Plass et al., 2010). The most commonly adopted subjective measures are unidimensional. These are the Subjective Rating of Perceived Mental Effort (Paas and Van Merriënboer, 1993) combined with Subjective Rating of Perceived Task Difficulty (Paas and Van Merriënboer, 1994; Paas et al., 2003). Paas (1992) equals the effort of learners to overall cognitive load, thus mental effort alone can measure the different types of load. In Paas and Van Merriënboer (1993), 'Mental effort may be defined as the total amount of controlled cognitive processing in which a subject is engaged'. Through a measure of mental effort it is possible to get information about the cognitive costs of learning, therefore predict the performance of learners. Objective measurement of cognitive load through various means have been proposed, as summarised in Plass et al. (2010). These means include learning outcomes (Mayer, 2005; Mayer and Moreno, 1998), time-on-task (Tabbers et al., 2004), task complexity (Seufert et al., 2007), behavioural data (Van Gerven et al., 2004), secondary task analysis (Brünken et al., 2002) and Eye-tracking analysis (Folker et al., 2005). Both subjective and objective measures of cognitive load have been combined in Paas et al. (2003). Here, cognitive load is the relation between invested effort and learning outcome. In summary, most of the measurement techniques present in the literature of education are mainly proxies to infer cognitive load. The situation is different in Ergonomics. Here, the measurement of MWL is an extensive area (Longo and Leva, 2017) where several assessment techniques have been proposed (Cain, 2007; Tsang, 2006; Wilson and Eggemeier, 2006; Young and Stanton, 2004, 2006; Moustafa et al., 2017): a) *self-assessment measures*; b) *task measures*; c) *physiological measures*. The category of *self-assessment measures* is often referred to as self-report measures. It relies on the subject perceived experience of the interaction with an underlying interactive system through the direct estimation of individual differences such as the emotional state, attitude and stress of the operator, the effort devoted to the task and its demands (De Waard, 1996; Hart, 2006). It is strongly believed that only the individual concerned with the task can provide an accurate judgement with respect to the MWL experienced. The class of *task performance measures* is based upon the assumption that the mental workload of an operator, interacting with a system, gain relevance only if it influences system performance. Primary and secondary task measures exist including reaction time to a secondary task or number of errors on the primary task or completion time (Rubio et al., 2004a; Tsang and Vidulich, 2006). The category of *physiological measures* considers bodily responses derived from the operator's physiology (heart rate, pupil dilation etc). These responses are believed to be correlated to MWL and are aimed at interpreting psychological processes by analysing their effect on the state of the body. Their advantage is that they can be collected continuously over time, without requiring an overt response by the operator (O' Donnel and Eggemeier, 1986) but they require specific equipment and trained operators mitigating their use in real-world tasks. Self-assessment measures have always attracted many practitioners and seem to be the right candidates for adoption in education. The following section describes two of these as their are adopted in the experiment of section 3.

2.4.2 The NASA-TLX and the Workload Profile

Two well known multi-dimensional subjective measures are the NASA-task Load Index (NASA-TLX) Hart and Staveland (1988) and the Workload Profile (Tsang and Velazquez, 1996). In contrast to unidimensional scales of mental load measurements such as effort and task difficulty proposed in Paas and Van Merriënboer (1993, 1994) and Paas et al. (2003), they focus on different components of load. In education, these are not widely employed, but a few studies have confirmed their validity and sensitivity (Gerjets et al., 2006; Kester et al., 2006; Gerjets et al., 2004). In general, the NASA-TLX has been used to predict critical levels of mental workload that can significantly influence the execution of an underlying task. The NASA-TLX consists of six sub scales that represent somewhat independent clusters of variables: mental, physical, and temporal demands, frustration, effort, and performance (Hart and Staveland, 1988). To recollect ratings for these dimensions twenty grade scales are utilised. A score from 0 to 100 (assigned to the nearest point 5) is collected on each scale from respondents. To connect the six individual scale ratings into an average score, a weighting calculation is used. This procedure requires a paired comparison task to be performed prior to the workload assessments. Paired comparisons demand the operator to select which dimension is more pertinent to workload over all pairs of the six dimensions. The number of times a dimension is chosen as more important, the weighting of that dimension scale for a given task for that operator is. A workload score from 0 to 100 is obtained for each rated task by multiplying the weight by the individual dimension scale score, summing across scales, and dividing by 15 (the total number of paired comparisons).

$$NASA : [0..100] \in \Re \quad NASA = \left(\sum_{i=1}^{6} d_i \times w_i \right) \frac{1}{15}$$

The Workload Profile (WP) is a subjective workload assessment technique, based on the Multiple Resource Theory (MRT) of Wickens (1984). In this technique, eight factors are considered: perceptual/central processing, response selection and execution, spatial processing, verbal processing, visual processing, auditory processing, manual output and speech output. The WP procedure requires the operators to furnish the proportion of attentional resources, in the range 0 to 1, used during a task. The overall workload rating is calculated summing each of the 8 scores (Tsang and Velazquez, 1996). Formally:

$$WP : [0..100] \in \Re \qquad WP = \frac{1}{8} \sum_{i=1}^{8} d_i \times 100$$

2.5 Conceptual map for assessment

Concept maps are graphical tools aimed at organising and representing knowledge. The conceptual maps are useful learning tools because they display a concept's component visualising their relationships and organising the related thoughts. Conceptual maps focuses on the promotion of creativity, they improve the effective externalisation and visualisation of ideas, discovering new problem solving methods and measuring concept understanding (Cristea and Okamoto, 2001). They are built upon *concepts* that are usually enclosed in circles or boxes of some type, and upon relationships between them, usually explicated by a *linking line* connecting two concepts (Novak and Cañas, 2008). On this connecting line, *linking words or linking phrases* can be placed, aimed at specifying the relation between concepts. A word, or multiple words can be used to label a concept as well as one or more symbols (for example: '+' '/' '='). Propositions contain two or more concepts connected by linking words or phrases to form a meaningful statement (Novak and Cañas, 2008). The concepts are visualised in a hierarchical structure starting from the most inclusive to the less. They are grounded on a key question related to some context and the links between different sections and an area of the map are called *cross-link*. The ability to draw a good hierarchical structure and the ability to find and characterise new cross-links promote the creative thinking phase.

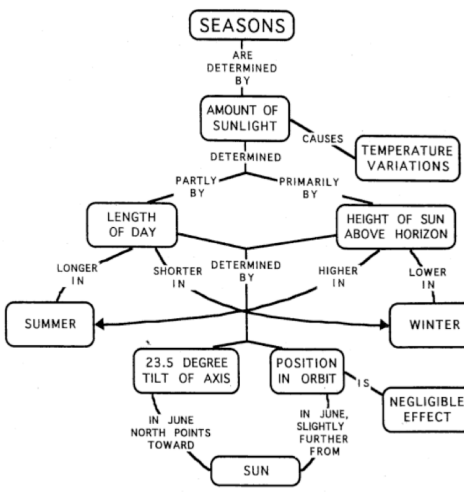

Figure 1: Example of a concept map (Novak and Cañas, 2008)

The criteria for measuring conceptual understanding is the reason why we are interested in Novak's conceptual maps. This type of maps are objective and meaningful assessment tools to evaluate an instructional design in the classroom. They are expected to be effective to identify both valid and invalid ideas grasped by learners and they can provide quantitative information about the student performance (Novak and Cañas, 2008). A rubik for quantitatively assessing a conceptual map has been proposed as per figure 2 Markham et al. (1994).

Element	Definition (Jones & Vesilind, 1994)	Points
Concepts *represent major ideas*		1 pt. for each concept
Relationships *indicate the extent of domain knowledge*	connecting lines and linking words between two concepts, between a concept and an example, or between two examples	1 pt. for each valid relationship
Branching *represent progressive differentiation in the knowledge domain*		1 pt. for the first branching 3 pts. for each successive branching
Hierarchies *represent knowledge subsumption*	connections among concepts and examples, from general to specific	5 pts. for each hierarchy
Crosslinks *reflect the extent of knowledge integration and synthesis*	connections between a segment of one hierarchy and a segment from another hierarchy	10 pts. for each crosslink
Examples *represent specificity of knowledge*	specific events or objects that are judged as valid instances of a concept	1 pt. for each example

Figure 2: Rubik for concept maps (Markham et al., 1994)

3 Design and methodology

A primary research study is envisioned. A number of different topics will be delivered by a number of selected lecturers using two teaching conditions:

- a traditional cognitivist activity (section 2.1), in which the instructor presents explicit information.
- a social constructivist activity added to the first, based upon trigger questions (section 2.2).

The experiment will involve students, of third-level classes, divided in two groups: a control group, receiving condition 1, and an experimental group, receiving condition 2. The goal of the trigger questions (as defined in table 1) is to support the development of the cognitive skills of learners. The list has been formed through a selection of the questions originally proposed in Sátiro (2006) that can be also applied in third-level contexts. After the completion of each class, students will be provided with a copy of the NASA-TLX or the Workload Profile questionnaires by a lecturer. Subsequently, an assessment of the information received by the lecturer, based on the use of conceptual maps, as described in section 2.5, will be distributed to learners (table 2). The basic idea of the graphic representation, through the use of conceptual maps, corresponds to coordinate the cognitive construction of schemata of knowledge with its externalisation (van Bruggen et al., 2002). The pedagogical goal is to improve the metacognitive skills by asking questions aimed at monitoring and controlling the transfer (and the construction) of information from working memory to long-term working memory and retrieving the schemata from long-term memory to working memory (Valcke, 2002). It is supposed that, the externalisation of the internal cognitive schemata of knowledge by sharing collaborative activities, improves metacognitive thinking, facilitating the learning process. It is important to note that the schematic performance test will be evaluated by the quantitative marking scheme developed by (Novak et al., 1984) and extended by (Markham et al., 1994) (Figure 2). This scheme will generate a score of performance in percentage. With an overall index of mental workload and a performance score, the proposal is to combine these two measures towards an index of efficiency. This will serve as a metric for the empirical evaluation of the two envisioned teaching conditions. In details, efficiency will be computed employing the Relative Efficiency measure proposed in Paas and Van Merriënboer (1993) (equation 1), updated with the overall score of mental workload – as measured by the NASA-TLX and WP – (figure 4).

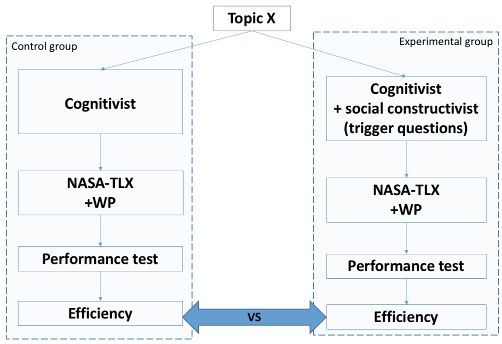

Figure 3: Schematic representation of the envisioned primary research experiment

$$Efficiency = \frac{|R-P|}{\sqrt{2}} \tag{1}$$

where P is the standardised performance score (in percentage) and R is the standardised mental workload score. If $R-P<0$, then E is positive, and if $R-P>0$, then E is negative.

4 Expected contribution

Different contributions to the body of knowledge are expected from this research. The first is the use of the NASA Task Load Index (Hart and Staveland, 1988) and the Workload Profile (Tsang and Velazquez, 1996) instruments as multidimensional sub-

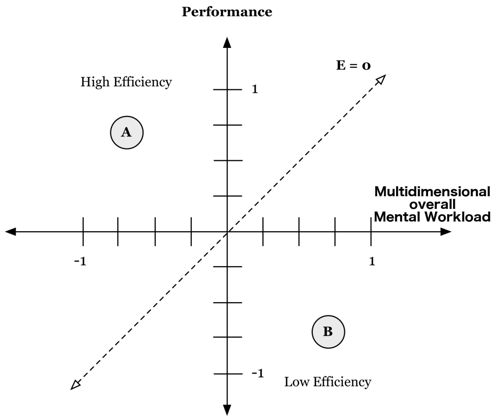

Figure 4: Instructional efficiency graph, adapted from Paas and Van Merriënboer (1993) by incorporating an overall measure of mental workload

jective measures of mental workload in third-level educational contexts. This is in contrast to most of the studies in the literature that have employed unidimensional mental workload subjective assessment techniques. The second expected contribution is the use of a social constructivist approach jointly with a traditional cognitivist approach to teaching. The novelty of this social constructivist approach is the use of trigger questions in a shared dialogue, this aimed at increasing the metacognitive skills of learners and support creative and critical thinking. This metacognitive activity is supposed to facilitate the control of information during the transfer and the construction phase. The third contribution is the extension of the relative measure of efficiency, proposed in Paas and Van Merriënboer (1993), with an overall measure of mental workload instead to perceived effort.

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Appendix

Conceptualisation	
Classifying and ordering	
1	From the information that you have received, what is the most important?
Conceptualising and defining	
2	What does ... mean?
Giving examples	
3	Could you provide some examples of ... ?
Comparing and contrasting	
4	Could you explain the differences and the similarities between ... and ...?
Investigation	
Generating hypotheses	
5	Which explanations could we provide to state that ... ?
Finding alternatives	
5	Are there some different way to state that ... ?
Reasoning	
Giving reasons	
7	Why do you think that....?
Connecting causes and effects	
8	What is the cause of.... and its effects?

Table 1: Trigger questions for supporting the development of cognitive skills - To be completed by instructor and to be answered by learners.

#	Question
NT_1	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
NT_2	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
NT_3	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
NT_4	How hard did you have to work (mentally & physically) to accomplish your level of performance?
NT_5	How successful do you think you were in accomplishing the goals, of the task set by the lecturer? How satisfied were you with your performance in accomplishing these goals?
NT_6	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Table 2: The NASA Task Load Index

#	Question
WP_1	How much attention was required for activities like remembering, problem-solving, decision-making, perceiving (detecting, recognising, identifying objects)?
WP_2	How much attention was required for selecting the proper response channel (manual - keyboard/mouse, or speech/voice) and its execution?
WP_3	How much attention was required for spatial processing (spatially pay attention around)?
WP_4	How much attention was required for verbal material (eg. reading, processing linguistic material, listening to verbal conversations)?
WP_5	How much attention was required for executing the task based on the information visually received (eyes)?
WP_6	How much attention was required for executing the task based on the information auditory received?
WP_7	How much attention was required for manually respond to the task (eg. keyboard/mouse)?
WP_8	How much attention was required for producing the speech response (eg. engaging in a conversation, talking, answering questions)?

Table 3: Workload Profile