The Assessment Scale for Creative Collaboration (ASCC) Validation and Reliability Study

Aekaterini Mavri[1][0000-0002-5076-5891], Andri Ioannou[1][0000-0002-3570-6578] and Fernando Loizides[2][0000-0003-0531-6760]

[1] Cyprus Interaction Lab, Department of Multimedia and Graphic Arts, Cyprus University of Technology, 30 Archbishop Kyprianou Str. 3036 Limassol, Cyprus

[2] School of Computer Science & Informatics, Cardiff University, Cardiff, CF24 3AA, UK

THE ASSESSMENT SCALE FOR CREATIVE COLLABORATION (ASCC) VALIDATION AND RELIABILITY STUDY

Abstract

Creativity, a primary academic objective, is crucial in higher education, as economic, informational, societal and environmental advancements rely on people's ability to innovate. Creativity is widely investigated in its individualistic form, yet there is a notable dearth in work that studies its collective dimension, from a learning perspective.

This study focuses on validating the psychometric properties of an existing instrument (ASCC), by measuring creative collaboration in blended learning settings. Two hundred and thirty six under and post-graduate students self-evaluated their creative collaboration experiences, using the ASCC instrument. The findings of exploratory factor analysis denote a three-factor (21-item) structure, measuring 'Synergistic Social Collaboration', 'Distributed Creativity', and 'Time Regulation and Achievement', with good internal consistency.

An instrument with valid psychometric properties for the assessment of creative collaboration is much-needed in the growing research and practitioners' community. This is critical in the fields of Design, HCI and Engineering, that rely extensively on the creative collaboration (online and offline) of teams to develop innovative products that are suitable for real-world purposes.

Keywords: Creative collaboration, social creativity, higher education, HCI, instrument development

THE ASSESSMENT SCALE FOR CREATIVE COLLABORATION (ASCC) VALIDATION AND RELIABILITY STUDY

Introduction

Creativity has been at the center of the Higher Education (HE) agenda for more than a decade, as a prerequisite for innovation and growth and a strong attribute required of graduates entering the knowledge industries today (Binkley et al., 2012; Botma, Van Rensburg, Coetzee, & Heyns, 2015; WEF, 2016). Being a multi-dimensional construct, respective research challenges lie in identifying the elements required for its fruitful practice, and most importantly, its evaluation. However, scholars raise a point about the area of creativity being in need of more exhaustive and targeted investigation (Batey, 2012; Sternberg, 2005). Specifically, to-date, there is a lot of work, focusing on organizational settings, while the area of creativity in *education*, particularly in the areas of Design, HCI, and Engineering studies, falls short of investigation. Additionally, *collective* or *distributed* – versus *individual* – creativity, appears largely under-explored in literature, especially at times when social learning approaches are prevalent in HE (Harvey, 2014; Sawyer & DeZutter, 2009; Yuan & Zhou, 2015). Social creativity or "*creative collaboration"* (Wishart et al., 2011) cannot be overlooked, as it can produce far richer results, than those generated by the sum of multiple individualistic contributions (Csikszentmihalyi & Hunter, 2003).

The role of creativity in HCI research, education and practice is central. It is an underlying factor for the people-driven, problem-oriented, experimentative and collaborative development of novel, usable and safe products (systems, tools) for the end-user (McCrickard, Wahid, Branham, & Harrison, 2013; Oulasvirta & Hornbæk, 2016). Although deemed important decades ago, creativity has only recently claimed a position in HCI (a computer science discipline) education and practice. Yet, creativity research, under the lens of HCI, lacks perspective and unity, as it is largely concerned with designing creative systems, rather than aiming to support the entire creativity processes of users (Hoffmann, 2016; Kantosalo & Toivonen, 2016). In order to achieve that, it should adopt an inter-disciplinary approach, encompassing both perspectives of HCI - *humans* and *computers* - drawing from research on both generic (psychology) and computational (computer science) creativity, thus accelerating the “process of disciplinary convergence” (Shneiderman et al., 2006).

Through this work, we attempt to contribute towards this effort, as we aim to inform about one of the ways that *human, creative collaboration* to be exact, can be measured and understood, through the use of a psychometric instrument. Further, since this instrument concerns *blended education*, the role of technology in supporting creative collaboration is central. Although the instrument does not focus on the affordances of a particular tool, but rather on the *creative collaboration* that ensues as a result, it is still of primary interest to HCI research.

This instrument probes for perceptions of creative collaboration in student teams who work in blended learning settings. Part of the motivation for this stems from our interest in employing the instrument in the area of Design education and related fields, such as HCI and Engineering. These fields are largely human-centered and rely extensively on the team’s social infrastructure and their ensuing collaborations, for the development of innovative products that are suitable for real-world purposes (Jeon, Fiebrink, Edmonds, & Herath, 2019; L. Dym, Agogino, Eris, Frey, & Leifer, 2005; McCrickard et al., 2013).

In specific, through this work we seek to validate the psychometric properties of this instrument, namely, the *Assessment Scale for Creative Collaboration* (ASCC), that resulted from the work of the European-funded CoCreat LifeLong Project (Wishart et al. 2011). Reliability findings, based on the scale’s initial 25-item structure, were reported in the original work – yet – the instrument’s psychometric properties were never assessed. This study aims to perpetuate the results of the original work by seeking to:

a) Present the ASCC 's subscale structure and derive respective reliability results
b) Explain the conceptual relationships of the subscales' variables, guided by the original work and how these relate to creativity-oriented HCI research

Overall, it is important for researchers to possess established and scientifically sound measures to address various *creativity* dimensions, in order to enable and foster them accordingly in HE. Specifically, when learning is guided by *social* perspectives, an instrument that measures *creative collaboration* in teams in natural settings, is largely missing from literature and can make a valuable contribution to the field.

The following sections focus on related research in the areas of creativity, through a general as well as an HCI perspective. The ASCC is then thoroughly described, followed by the methodology used for its validation. Finally, the quantitative findings and the scale's factor structure are discussed.

Related work

Generic and HCI-oriented creativity

Creativity is a critical skill and claims a prominent place in educational research (Crilly & Cardoso, 2017). Although primarily linked to artistic endeavours, research suggests that it is also crucial in the science, technology, engineering, business and education disciplines (Cropley, 2015; Kaufman, Plucker, & Russell, 2012; Wagner, 2017).

Most contemporary theories share the view that creativity is seen as the 'expressions or outcomes that are both novel as well as appropriate for a purpose' (Amabile & Pillemer, 2012; Bruner, 1962; Furnham, Batey, Booth, Patel, & Lozinskaya, 2011; Kaufman & Baer, 2005). Amongst many, its most important sub-constructs refer to *innovation* and *divergent thinking*, perceived as a type of lateral, experimental, intuitive, risk-taking, affective and generative approach (Onsman, 2016). *Convergent thinking*, on the other hand, a similarly vital component of creativity, is seen as an associative, integrative, critical-thinking step, that focalizes and extracts judgments from arbitrary and diverse ideas, guided by the specific *purpose* of the task at hand (Jaarsveld, Lachmann, & van Leeuwen, 2012).

Appropriateness for a *purpose* - often a real-world one - is a crucial component of creativity (Chilana, Ko, & Wobbrock, 2015; Finken, Culén, & Gasparini, 2014). Sufficient prior *subject-knowledge* is also important for achieving this *generative* and *integrative* activity (divergent/convergent thinking), as the *reuse* of earlier knowledge facilitates the production of new knowledge in the context of a purpose (McCrickard et al., 2013).

These key sub-constructs highlight and justify the inevitable link between *creativity* and HCI. Before we begin analysing this rationale, we need to mention that their connection can be understood in light of two perspectives. Firstly, creativity as an *integral component* of *HCI education and practice*, and secondly, creativity as the *object* of *study in HCI*, that is, the ways in which HCI can support human creativity via technology. Both link back to the rationale of this research and are explored below.

Creativity in HCI education and practice

HCI education and practice presuppose the actions of both *finding* and *making*; that is exploring and understanding human-computer-related phenomena and using these to support the *ideation* and transformation of concepts "into new constructs" (Finken et al., 2014). This occurs through critical questioning and problem-solving processes, to develop and deliver novel, safe and usable products to the end-user (McCrickard et al., 2013; Oulasvirta & Hornbæk, 2016).

Interaction design in HCI, has been recently seen to follow *design thinking*, a model that promotes *open-endedness* and "creative-insight" (Finken et al., 2014; Pierce et al., 2015) as fundamental for the development of novel products that can respond to the complex user needs of today (Candy, 2013; Frich, Biskjaer, & Dalsgaard, 2018). Design thinking involves a cyclical, yet, non-linear process of *inspiration*, *ideation* and *implementation.* Collective brainstorming, the expansion of the *problem-space* through multiple perspectives and ideas, visual externalizations (i.e. prototyping) and user-testing, are considered as key for the production of innovative solutions (Bhatnagar & Badke-Schaub, 2017; Zimmerman & Forlizzi, 2014). Agreeing with this model, the interaction design processes are also predominantly collaborative, materializing in -ideally- multidisciplinary team conditions (i.e. HCI researchers, programmers, designers, psychologists) to stimulate diverse inspiration and knowledge (Bardzell, Bardzell, & Koefoed Hansen, 2015; Culén, 2015; Pierce et al., 2015). Since contemporary HCI relies on a people-first, innovation-oriented and experimentation-driven rationale, it is fair to say that *creativity* and *collaboration* are therefore crucial components of HCI research, education and practice.

Creativity as the object of study in HCI

Creativity and *collaboration* – specifically the ways in which they can technologically be supported - are relatively new in HCI (Frich et al., 2018). As *creativity-oriented-HCI* research has so far been concerned with *computational creativity*, that is solely on designing *creative systems*, it is considered to be 'fragmented' as it lacks the perspective of supporting the entire process of human creativity – both individual and collective. This can evidently be augmented through the contribution of work from generic creativity research (CR), a subdomain of *psychology* research (Hoffmann, 2016).

Specifically, to design systems that enable and promote *creativity*, HCI needs to broaden its investigation with fundamental CR variables, such as the *people*, *processes*, *products* and *context* (Rhodes, 1961). Drawing knowledge from multiple domains constitutes a more compound research approach and helps shape a well-rounded and substantiated understanding of human creativity and collaboration, accelerating the "process of disciplinary convergence" in this way (Shneiderman et al., 2006). There is a current critical need for joint research, accommodating phenomena that fall under the lens of *creativity* on both *computers* and *humans,* as the two main areas of interest in HCI (Hoffmann, 2016).

Creativity assessment perspectives and strategies

The assessment of creativity has generated considerable discussion over the years (Runco, 2007). Dimensions such as the individual creative-cognitive abilities, personality traits and inclinations (Crilly & Cardoso, 2017), the creative process (Mednick, 1962), the social context (Plucker, Beghetto, & Dow, 2004), the epistemic domain (Furnham et al., 2011; Kaufman & Baer, 2005) and the creative outcomes (Horn & Salvendy, 2006; Zeng, Salvendy, & Zhang, 2009), indicate that creativity warrants dedicated specificity in its research and analysis (Mumford, 2003).

Assessment strategies have so far included verbal or written protocol analysis (D'souza & Dastmalchi, 2016; Gero & Kan, 2016), behavior and activity-based tests (Torrance 1966), observation (Meneely & Portillo, 2005), psychometric instrumentation (Plucker et al., 2004; Runco et al., 2014) and external creativity assessment of products (Amabile, 1982; Horn & Salvendy, 2006; Zeng et al., 2009). The majority of these look into individual dimensions of creativity such as personality attributes and performances (Runco, 2007). Some of the most prevalent tests operationalized towards this direction, include the 'Torrance Test of Creative Thinking' (TTCT) (Kim, 2006; Torrance, 1966), the 'Kaufman Domains of Creativity Scale' (K-Docs) (Kaufman & Baer, 2005), and the 'Creativity Assessment Battery' (rCAB)© (Acar & Runco, 2014).

Social collaborative creativity assessment

The assessment of social creativity is still under-explored in literature (Farh, Lee, & Farh, 2010; Harvey, 2014; Kurtzberg & Amabile, 2001; Paulus & Baruah, 2018; Yuan & Zhou, 2015). A few studies have concentrated on qualitative observations of brainstorming teams to document their collaborative creativity (Paulus & Nijstad, 2003). Others detected and categorized *distributed* creative collaboration, through protocol coding, using interaction models (Sawyer and DeZutter 2009) and computer-mediated analysis of activity and discourse (Karakaya & Demirkan, 2015; Scott, 2015) . As part of an inclusive approach, Batey (2012) provides an effective, all-encompassing, three-dimensional taxonomic framework for the analysis of creativity, depending on the research objectives. It covers three axes : a) *level*, referring to the individual, team, organization or culture dimensions b) *facet*, referring to the *trait, process, press* or *product* dimensions, and c) *measurement*, referring to the objective, self-rating and other-rating dimensions. With regard to *team* and collaboration, he proposes that results can be extracted from a *team-rated creativity questionnaire*, through the sum of the individually submitted scores. In this work, we adopt this recommendation and proceed to validate the ASCC, to be used in such approaches. As discussed, the scale probes for accumulated perceptions of a team's *creative collaboration* processes, in blended learning settings. From an HCI perspective, basic usability (effectiveness, efficiency driven) and task-oriented assessment methods (i.e. user clicks, time-to-completion etc) are not sufficient for capturing its *complex* nature, as a multi-faceted creativity construct. These methods have often been criticized for limiting understanding based on objective and controlled, (i.e. in-vitro) findings only, which are in conflict with the illstructured, open and exploratory nature of creativity (Frich et al., 2018; Shneiderman et al., 2006). Research on this multi-dimensional construct, should aim to investigate the real situated experiences of the people involved instead, particularly in terms of the cognitive, perceptual and affective perspectives (Candy, 2013; Hassenzahl, 2004).

Contributing to the required shift from *task* to *value*-oriented techniques are - amongst others - the category of reusable, *self-reported* measures, such as psychometric instruments, that HCI researchers can use to extract information about targeted dimensions of *creativity* and *collaboration*, especially when they are also supported by technological means (Cherry & Latulipe, 2014). An instrument with psychometric properties aimed at measuring *creative collaboration* in blended learning settings, is therefore a much useful tool. That said, depending on the objectives of a study, research rigor can be further enhanced by triangulating findings from various other techniques (observation, interviews, focus-groups, artefact assessment), that can contribute new findings and make a difference to HCI research (Candy, 2013; Shneiderman, 2007).

Overall, an instrument with psychometric properties aimed at the assessment of *creative collaboration* is highly needed in the research of creativity in blended settings in HE, as it is virtually absent from current literature. In the next section, we briefly describe the Assessment Scale for Creative Collaboration (ASCC), as the CoCreat Lifelong Learning Project's attempt in the development of a self-rated instrument.

The Assessment Scale for Creative Collaboration (ASCC)

The ASCC (Wishart et al. 2011) investigates perceptions of the key concepts of *creative collaboration* in computer-supported collaborative learning (CSCL) settings. Wishart et al. (2011) focus on the dimension of 'creative collaboration' by adhering to primary CSCL theories (Dillenbourg, Järvelä, & Fischer, 2009; Lew, Park, Lee, & Kang, 2013). They explain their choice of the term, as the 'collaboration process between people, working on collective tasks in the creative or other industries'. They posit that this process is initiated by ill-defined problems, driven by a series of acts of *imagination*, *divergent thinking* and *problem solving*, leading to *novel* as well as *useful* outcomes.

The instrument looks at creativity from different angles, drawing from social perspectives, factors of *interest*, together with learning *regulation* theories, to derive a compound result. Specifically, through its original 25-item structure, it seeks to elicit participant perceptions of the team processes that relate to divergent and critical thinking, the management of ill-defined problems, the role of prior subject-level knowledge, the social perspectives of co-located and distant collaboration, the level of interest and engagement in a task, and individual or group time-pressure and management.

Materials and methods

Participants

A total of 236 undergraduate and postgraduate students, with recent sufficient collaborative work history, completed the ASCC's questions using a 7-point Likert scale. The participant sample falls close to the ten observations-per-item approach, which indicates a 'fair to good' analogy (Barlett, Kotrlik, & Higgins, 2001; Gorsuch, 1983; Pearson & Mundform, 2010). Participants were prompted to consider their most recent collaborative experience as part of their academic responsibilities, for completing the questionnaire.

Parallel analysis

We conducted Parallel Analysis, prior to factor analysis, to identify the statistically significant factors (eigenvalues) that should be obtained from the scale (O'connor, 2000; Wood, Akloubou Gnonhosou, & Bowling, 2015). We used a permutation approach for running the Parallel Analysis (PA), as it is reportedly an appropriate and robust method for multivariate non-normal data (O'connor, 2000). A three-factor structure (agreeing with the eigenvalue of >1 criterion (Kaiser, 1960), was extracted from the 25 variables of the ASCC questionnaire.

Results

Exploratory factor analysis (EFA)

Descriptive statistics resulted in item means of an average range of 4,2 – 5,7 (M=5,1). A standard deviation of above 1, also indicated satisfactory diversity in the responses (SD=1,46). No variable redundancy was detected in the correlation matrix table (Pett, Lackey, & Sullivan, 2003).

We adopted a Principal Axis Factor (PAF) extraction and the Oblimin Oblique rotation method (delta=0) in the EFA, based on the prediction that ASCC variables would be correlated, as it frequently occurs in social studies (Reise, Waller, & Comrey, 2000). The results indicated a general positive manifold in the data. The measure for sampling adequacy (Kaiser-Meyer-Olkin) produced an optimal result (,913) (Dziuban & Shirkey, 1974). We also extracted a significant value ($\chi 2$ (300) = 3117,52 $p < .001$) after conducting the Bartlett's test of sphericity, in measuring homogeneity in the correlation matrix (Scott, 2015).

The three resulting factors comprised 47,28% of the total variance in the ASCC variables. Factor eigenvalues and corresponding total variance percentages are presented in Table A1.

Insert Table A1 Here

The within-variables approach indicated a moderate to high level of common variance based on the extracted communality values: >.5 accounted for the 48%, > .4 accounted for the 40% and <.4 for the rest (Thompson, 2004).

The *rotated pattern matrix* (pattern coefficients) results indicated an initial set of 11 variables for Factor 1, 7 variables for Factor 2 and 7 variables for Factor 3, with some degree of cross-loadings. We only retained variables that had:

a) a pattern coefficient of 0,4 and above

b) significant differences in the value (approximately ≥ 0,20), in cross-loading items (Loiacono, Watson, & Goodhue, 2002; Netemeyer, Bearden, & Sharma, 2003)

During post PAF processing, we made qualitative judgements about the deletion and retention of variables (see Table A2). The final resulting subscale structure, following reliability analysis, is presented in Table A4. Variables 3, 6 and 9 (see Table A2) were the only ones that did not cross-load on other factors. However the rest, were retained at this stage, as they complied with retention criterion (b).

Factor 2 loaded with a total of 7 items. We chose to retain item 18 that failed criteria (a) and (b), because of its critical *conceptual* significance (divergent thinking) in the construct of creativity.

Factor 3 loaded with a total of 7 items. Variables 24 and 25 did not comply with retention criteria (a) and (b) and were therefore dropped from this factor. Factor 3 resulting structure included a total of 5 variables.

Insert Table A2 Here

Reliability analysis

We investigated the ASCC's subscales' reliability (internal consistency reliability) and sought to comply with the following criteria:

a) A minimum of α = 0,70 for *Cronbach's alpha coefficient* for all subscales (Cronbach, 1951). Newly developed scales may produce values of as low as 0,7 (Fornell & Larcker, 1981; Lance, Butts, & Michels, 2006). Likewise, values that fall higher than 0,9 need to be revisited to examine issues of redundancy.
b) A range of values between 0,3 and 0,7 for *inter-item correlations*, denoting homogeneity but no redundancy (Pett et al., 2003).
c) Small values (≤ .1) for inter-item-correlation *standard deviation* (Pett et al., 2003)
d) A range of values between 0,4 and 0,75 for corrected *item-to-totals* as indicated in the *item-to-total* statistics results (Loiacono et al., 2002; Netemeyer et al., 2003).

Below we present individual subscale reliability results.

Insert Table A3 Here

Subscale 1

We concluded an optimal level of internal consistency at α = ,92 for this subscale (Cronbach, 1951). With the exception of items 1, 2 and 4 (with values above 0,7), the rest of the items in the subscale fell within the acceptable inter-item-correlation range. The *item-to-total* correlation results indicated that items 1 and 2 exceeded the acceptable *upper* limit and were removed from the subscale. Item 4 was retained as a critical conceptual variable (interest) relating to the construct of creativity. A second reliability analysis test on the subscale's 9 variables, produced a high Cronbach's value of α = ,89 (see Table A3).

Subscale 2

Reliability test analysis on the subscale's 7 items resulted in a satisfactory Cronbach's value of a= ,77 (see Table A3). Item 14 of the subscale failed to comply with the *lower* value criterion in the *inter-item-correlation* range. However we judged that the variable should be retained, due to its association with both the creativity and collaboration constructs (Hsiao, Wang, & Chen, 2017; Ohly & Fritz, 2010; Prem, Ohly, Kubicek, & Korunka, 2017).

Subscale 3

Reliability analysis on the subscale's 5 items resulted in a satisfactory Cronbach's value of a= ,76 (see Table A3). The subscale presented an item (22) that failed to meet the minimum value (0,3) in the *inter-item-correlation* matrix (0,29), but was maintained as it is strongly associated with creativity and related constructs in literature (Losada, 1999; Valiente, Swanson, & Eisenberg, 2012) (see Table A4).

The test for reliability produced high alpha values (α ≥ ,70) for all subscales, hence, overall, the instrument presents high internal consistency reliability.

Insert Table A4 Here

Discussion

The objective of this work was to perform an initial validation of the ASCC's psychometric properties, due to the vast lack of self-reported instruments that measure creative collaboration in teams, based on existing research. The EFA produced three subscales (totaling 21 items) for assessing ‘Synergistic Social Collaboration’, ‘Distributed Creativity’, and ‘Time Regulation and Achievement’. The instrument presented high internal consistency reliability, based on Cronbach's alpha values, with sound conceptual inter-item relationships. These are discussed below.

Subscale 1: Synergistic social collaboration

The choice of term for this subscale relies on the crucial role of the *synergy* amongst collaborating team-members for the production of greater results than the mere sum of separate individual parts. The nine-variable subscale contains factors of *co-present* and *remote* CSCL. At its core lies a set of variables related to *cognition*, such as a developed sense of understanding peers’ viewpoints, grounded in affective factors such as *trust*, *support* and a ‘sense of belonging’ in the team (see Table A4).

Interest, an intrinsic motivational variable, is closely related to creativity and collaboration in literature and frequently occurs in the subscale (Hoskins & Van Hooff, 2005). The construct of *interest* (often linked to engagement) encompasses both affective and cognitive attributes (Krapp, 1999), denoting awareness of one’s own knowledge and competencies, as well of what can socially and conceptually be transmitted (i.e., ‘Shared knowledge and goals’) (Renninger, Hidi, Krapp, & Renninger, 2014)(Wentzel & Miele, 2009). Eccles’ expectancy-value model (1983) denotes *interest* as a fundamental component of its *task-value* factor (i.e. the perceived worth of an academic task), as well as the force that drives the successful *completion of tasks* (i.e., ‘Orientation towards task success’) (Wigfield & Eccles, 2000). The high correlation values between the two variables - ‘Group Interest’ and ‘Task Success’ (r = ,664) - in the *inter-item correlation* matrix also confirm the strong conceptual link between the two (see Table A5).

The produced links between the variables in the subscale, are well supported by evidence from literature. For instance, the extensive *generation* and *analysis of ideas* ('Discussion of early ideas') is related to natural inquisitions and *explorations* on behalf of learners and collaborators, which is the outcome of a growing *interest* and *engagement* in a subject area (Gehlbach et al., 2008). Another activity initiated by group *interest* – and also confirmed by the high correlational value (r = ,558) in the subscale's *inter-item correlation* matrix (see Table A5) - is the 'Discussion of early ideas' which is crucial in both creativity and collaboration in the learning context. The ASCC report posits that this variable - typically related to brainstorming activities - is prominently linked to literature on *collaborative creativity* (Mamykina, Candy, & Edmonds, 2002; Wishart & Eagle, 2012).

'Adequate knowledge base' is also repetitively encountered across theoretical domains. A sufficient level of *prior field-specific knowledge*, is for instance mentioned by Amabile (Amabile, 1982), in her componential theory of creativity, as a primary variable, rooted in social constructivist learning theories (Vygotsky, 1978) and a vital precursor to higher-level cognitive functions, during collaboration (Huang, Yang, Chiang, & Su, 2016). The results of this study (see Table A5) agree with existing work (Linnenbrink-Garcia, Pugh, Koskey, & Stewart, 2012) and confirm that *prior knowledge*, is a strong antecedent to *interest* and *engagement* in social learning settings.

Insert Table A5 Here

Subscale 2: Distributed creativity

This subscale is titled 'Distributed Creativity', after Sawyer's and DeZutter's (2009) definition, as pertinent conceptual variables are prominent within this.

The majority of work theorizing about creativity, focuses on 'Divergent thinking' and the generation of *innovative ideas* that are appropriate for a task (i.e., 'My group generated different and novel ideas in response to the task'). Theory also posits that 'messy' types of problems that lack explicit guidelines for their resolution (as those encountered in the real world), can augment and advance the collective creative thinking process ('Problem boundaries stretched or broken') (Brown & Duguid, 2001). Additionally, *collective creativity* that generates *innovation*, is known to flourish in a *trustful* and *respectful* environment – yet – one of a moderate 'Degree of disagreement and tension' (Chiu, 2008). This stems from the argumentative exchange that requires sound reflective reasoning on behalf of peers to prove and support their stances, during a collective creative task (Wishart et al., 2011). This view is also enforced in the study, due to the high correlation value between 'Degree of disagreement and tension' and 'Level of divergent thinking' (r = ,452) (see Table A6).

Tension in itself, can also be seen as a by-product of *engagement* and *interest* in a task, which is also contingent to the 'level and type of co-presence' (*formal/informal* and *offline/online*) – (i.e. 'Degree of co-presence'), meaning the availability and engagement of peers in the team's practice.

Time-pressure and *creativity* make another prominent pair in this subscale. Time-pressure is explained either as *actual*, imposed by external factors such as deadlines (Romero and Barberà, 2012), or *subjectively perceived* by individuals as 'lack of time' in managing their tasks (university projects or work-related outcomes).

Existing work draws a two-fold relationship between *time-pressure* and *creativity*. From one perspective, creativity is seen as hindered in contexts with severe time pressure, as it forces teams to work faster by making quicker, less-exploratory - hence – safer but less innovative choices (Amabile, Hadley, & Kramer, 2002; Baer &

Oldham, 2006). Another view posits that *mild-to-moderate* time pressure on the other hand, can act as a “challenge stressor” (Prem et al., 2017), sparking *motivation and* creative *effort* (Gardner & Cummings, 1988; Hsiao et al., 2017; Ohly & Fritz, 2010).

In terms of *co-presence* – both *formal* and *informal* – apart from the foreseen inter-item correlation amongst the two (r = ,544), we were able to elicit that a ‘Degree of (informal) co-presence’ is associated with ‘Externalizing representations’ (r = ,473). Interestingly this also happens between the latter and ‘Level of divergent thinking’ (r = ,476), in the sub-scale (see Table A6). As proven, creativity (in the form of divergent thinking) and *externalizations* in informal social collaboration are solidly inter-related in previous work (Vyas, Heylen, Nijholt, & Van Der Veer, 2009). Physical or digital externalizations (i.e. sketches, notes, three-dimensional paper prototypes) are used to mediate and reflect novel thoughts onto tangible objects. These “guiding, constraining, and determining” cognitive dimensions , form communicative, coordinative, explorative and reflective creative activity and occur amongst team members, in informal co-present contexts (also confirmed by the subscale’s inter-item correlations) (Amitani & Hori, 2002; Zurita, Baloian, Pino, & Boghosian, 2016).

Finally, the subscale demonstrates good inter-item correlations between ‘Group-based time pressure’ and ‘Stretching problem boundaries’ (r = ,463), while the latter also correlates well with a ‘Degree of disagreement or tension’ (r = ,443) (see Table A6). We notify the reader that ‘Stretching problem boundaries’ refers to the exploration of different possibilities, as opposed to ‘Stretching boundaries’ in subscale 3, which suggests surpassing the assigned task deliverables.

Insert Table A6 Here

Subscale 3: Time regulation and achievement

The title of this factor stems from the positive interaction between *learning regulation* (with *time regulation* as a main sub-construct) and *achievement*, based on relevant literature (Pintrich, 2004). 'Time regulation and Achievement' is a subscale comprising five variables. As anticipated the highest inter-item correlation (r = ,636) in the subscale appears between 'Individual' and 'Group-level time management' (see Table A7). *Time-management* and its three dimensions, *self-regulation*, *co-regulation* (pairs) and "socially shared regulation" (Hadwin, Järvelä, & Miller, 2011), appear as key constituents of *learning regulation* in literature (Pintrich, 2004; Stoeger & Ziegler, 2008). Social regulation reveals well-planned collective strategies, concerning time and effort, in purpose of attaining individual or collective knowledge and goals (Romero & Barberà, 2012).

Further, behavioral research illustrates the connection between *regulation* ('Group time-management') and *innovation*, as an accomplishment that surpasses the original expectations ('Stretching boundaries') (Britton & Tesser, 1991; Pintrich, 2004). Knowledge of self-ability, the purposeful planning of steps towards an end-goal, and adhering to that plan, through the systematic monitoring of timely activities is fundamental in achieving and transcending the end-goal ('We went beyond the task') (Hirst, Van Knippenberg, & Zhou, 2009). These two variables also presented good inter-item correlations (r=,463) in the subscale (see Table A7). Additionally, 'Group time management' is also positively correlated with the 'Level of imagination' (r = ,435), a term associated with *divergent thinking* and *creativity*, in related literature too. Specifically, *daily planning*, confidence of *long-term planning*, total *time-management* and perceived *control of time* and *tenacity*, are traits of creative individuals or teams that regulate their practice in aim of innovative performances (Darini, Pazhouhesh, & Moshiri, 2011; Zampetakis, Bouranta, & Moustakis, 2010).

Finally, existing research posits that 'Emotional expression' is closely linked to regulated learning, due to its significance in the *orientation* and *commitment* of individuals or teams, towards an end-goal (Prem et al., 2017). Sound socio-emotional workspaces have the capability to promote creativity, by cultivating feelings of *trust* and *inter-connectedness* amongst participants. Reversely, negative environments, with a *restrictive* and *distrustful* feel, can impede the levels of emotional expression, natural communication, experimentation, and can subsequently lead to poor creative outcomes (Valiente et al., 2012). 'Emotional expression' has a relatively low but positive correlation with achievement ('Boundaries Stretched') in this subscale (see Table A7).

Insert Table A7 Here

Significance of findings in HCI

Recently, a group of 32 HCI experts have identified and investigated the seven grand challenges that emerged from current and forthcoming technological and societal demands, which HCI is anticipated to address today (Stephanidis et al., 2019). *Creativity* and *Learning* combined, were one of the areas identified. Specifically, their work stressed the need to first understand and then cultivate the learning and transfer of creativity (particularly in CSCL and CSCW settings), in an effort to bring diverse skillsets together using technology, for the development of innovative products that have real-world impact. We agree with this assertion and add that in order to promote creativity in learning, we should also have the right tools at our disposal, that can readily frame it, particularly within real situated settings. We posit that the ASCC constitutes one such tool, which has literally been absent from literature up to now. Below we analyze the significance and contribution of each resulting subscale from our analysis, through an HCI lens.

Synergistic social collaboration. Inventivity, as a product of collaboration in HCI teams needs to be adequately measured (Wong, Kotze, Read, Bannon, & Hvannberg, 2007). This subscale aligns well with this HCI objective. It sees learning itself as a creative process, one that uses and customizes existing knowledge to generate new knowledge through *communication* and social interaction. It therefore places *prior domain-level knowledge* and the *understanding of others' knowledge*, as prerequisites of creative collaboration in teams. This agrees with HCI research, which also sees adequate prior knowledge as a key requirement for the design and evaluation stages in user-centered processes (Culén, 2015; Glăveanu, Ness, Wasson, & Lubart, 2019).

Additionally, over the recent years, HCI has been increasingly concerned with dimensions of *affect* and *emotions* that occur in the communication and work processes of teams, as well as in their exchanges with the technology that supports them (Hassenzahl, 2004; Heuer & Stein, 2019; Sanches et al., 2019). The importance of contextual factors (physical, social, technical) or what Rhodes (1961) labeled as 'Press' in his creativity framework, in generating a safe and supportive setting for team interaction, is prominent in recent creativity-oriented HCI research (Beckhaus, 2006; Candy, 2013; Hoffmann, 2016). It is also well understood, that to capture this wide range of affective factors, predictive or objective measures should be replaced by methods that gauge for the *real situated* experiences of people, *during* or *following* their interactions. These could be observations, interviews and questionnaires (Candy, 2013; Glăveanu et al., 2019). We believe that all of the resulting subscales of the ASCC, support this direction and constitute the means to achieve this. In line with the overall scale's attention to *affective* factors in creative team activity, this subscale specifically investigates perceptions of *trust* and *safety* (trust, safe atmosphere) that are critical in the *sharing of knowledge*, particularly early on in the project cycle (i.e. the ideation phase). It also agrees well with relevant HCI work which focuses on the factor of *interest* - often used interchangeably with engagement and motivation – as crucial for creativity (Deterding, 2012; Peters, Calvo, & Ryan, 2018). The subscale refers to *interest* both at the individual level, as well from the aspect of the technology systems that can stimulate and sustain it in collaborative teams.

The subscale also confirms previous usability-related findings that associate *interest* with better learning and increased tendencies for *higher achievements* (orientation towards success) (Zaharias, 2009). It thus provides a well-rounded approach to understanding affective factors in teamwork, which is highly relevant and useful for framing the creative collaboration of teams in HCI fields.

Distributed creativity. Corresponding to the rationale of creativity as one of HCI's grand challenges (Stephanidis et al., 2019), the 'Distributed creativity' subscale focuses on understanding the ways in which divergent ideas (divergent thinking) and novel results (stretching problem boundaries) can emerge from the collective efforts of co-present and remote teams. Amongst others, it pays attention to *externalizations,* as means of effective communication and as critical components in the design and evaluation stages. Artefacts such as conceptual designs, rapid prototypes, user flows and sitemaps, are fundamental in human-centered design procedures and should receive specific attention in the investigation of creativity in HCI teams (Culén, 2015).

The subscale also aligns well with the HCI focus on creativity support tools (CSTs) (Cherry & Latulipe, 2014). It examines how such tools can mediate team presence (co-presence) in *remote* locations and facilitate phenomena that are inherent in *co-located* settings, such as the *management of time pressure*, *disagreement* and *tension*. In moderate levels, these are reported as positive indicators of *interest* and can improve negotiation and problem-solving skills, thus enhancing the creative collaboration of teams in the HCI domain (deChambeau, 2017).

Time Regulation and Achievement. This subscale places predominant emphasis on the measure of both individual and collective *time-management* - a key component of learning regulation – which combined with freedom of *emotional expression* can significantly impact the level of *achievement* in teams (stretching boundaries) (Pintrich, 2004; Wolters, Won, & Hussain, 2017; Wong et al., 2007).

All these variables are practically relevant in any domain but have elevated significance in an HCI context. The concepts of *time* and *regulation* are central in information technology, UX design and software development, since these are highly collaborative, inherently inter-disciplinary and difficult to manage (Talone, Basavaraj, & Wisniewski, 2017). Over the recent years, product development in these fields has often been the result of distributed teamwork, giving rise to phenomena such as - for instance - the ‘global software development’ (GSD) model, which can reportedly minimize costs and achieve better deliverable quality by utilizing diverse expertise in remote settings (Chadli et al., 2016; Niazi et al., 2013).

Development teams, especially in such distributed environments, are required to apply rigorous techniques and methods to prioritize and monitor self and team-tasks, in order to timely deliver products (Alomar, Almobarak, Alkoblan, Alhozaimy, & Alharbi, 2016). The importance of *time-management*, has also given rise to a genre of software project management tools, built purposely to target the abilities, requirements and limitations of people in the field. Further, aptitude of time regulation, both on an individual and a collective level, is considered a competitive skill for graduates transitioning into the information technology industries today.

As creative processes and innovative results rely greatly on *time management* and related variables, we deduce that this subscale makes a meaningful contribution to HCI, through the measuring of how they are perceived by collaborative teams.

Conclusion

Recent HCI research denotes that creativity is vital in learning and should be “pursued in the context of current and future education curricula” (Stephanidis et al., 2019), whether these fall under the artistic or scientific disciplines. However, HCI reportedly still falls short of placing the promotion of creative thinking and inventivity at the top of its priority list (Culén, 2015). We propose it has a lot to gain from methods that transcend its disciplinary boundaries and methods, to measure the real situated perceptions of the people involved.

An instrument with psychometric properties measuring specific dimensions of *creative collaboration* is important in the community’s strive to promote *creativity* in education, especially in the Design, HCI and Engineering domains. *Creativity* in these fields is critical, as they are predominantly problem-oriented, human-centered, experimentative and collaborative, aiming towards the development of *novel*, *usable* and *safe* products for the end-user, all of which are constitutive dimensions of creativity.

In this study we examined the properties of an existing instrument, namely, the Assessment Scale for Creative Collaboration (ASCC), by a) determining its subscale structure and its internal consistency reliability and b) analyzing the conceptual relationships amongst their items and analyzing their significance in the HCI domain. Factor analysis produced a three-factor structure (21 items), namely, ‘Synergistic Social

Collaboration' (9 items), 'Distributed Creativity' (7 items), and 'Time Regulation and Achievement' (5 items), all with acceptable reliability scores. Future improvements involve the employment of a Confirmatory Factor Analysis (Briggs & Cheek, 1986; Netemeyer et al., 2003) to provide additional validity to the ASCC instrument.

References

Acar, S., & Runco, M. A. (2014). Assessing associative distance among ideas elicited by tests of divergent thinking. *Creativity Research Journal*, *26*(2), 229–238.

Alomar, N., Almobarak, N., Alkoblan, S., Alhozaimy, S., & Alharbi, S. (2016). Usability engineering of agile software project management tools. *International Conference of Design, User Experience, and Usability*, 197–208. Springer.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology*, *43*(5), 997.

Amabile, T. M., Hadley, C. N., & Kramer, S. J. (2002). Creativity under the gun. *Harvard Business Review*, *80*, 52–63.

Amabile, T. M., & Pillemer, J. (2012). Perspectives on the social psychology of creativity. *The Journal of Creative Behavior*, *46*(1), 3–15.

Amitani, S., & Hori, K. (2002). Supporting musical composition by externalizing the composer's mental space. *Proceedings of the 4th Conference on Creativity & Cognition*, 165–172. ACM.

Baer, M., & Oldham, G. R. (2006). The curvilinear relation between experienced creative time pressure and creativity: Moderating effects of openness to experience and support for creativity. *Journal of Applied Psychology*, *91*(4), 963–970. https://doi.org/10.1037/0021-9010.91.4.963

Bardzell, J., Bardzell, S., & Koefoed Hansen, L. (2015). Immodest proposals: Research through design and knowledge. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 2093–2102. ACM.

Barlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43.

Batey, M. (2012). The measurement of creativity: From definitional consensus to the introduction of a new heuristic framework. *Creativity Research Journal*, *24*(1), 55–65.

Batey, M., Chamorro-Premuzic, T., & Furnham, A. (2010). Individual differences in ideational behavior: Can the big five and psychometric intelligence predict creativity scores? *Creativity Research Journal*, *22*(1), 90–97.

Beckhaus, S. (2006). Seven Factors to foster creativity in university HCI projects. *Inventivity: Teaching Theory, Design and Innovation in HCI, Proceedings of of HCIEd2006-1 First Joint BCS/IFIP WG13. 1/ICS/EU CONVIVIO HCI Educators' Workshop, 23-24 March 2006, Limerick, Ireland*, 91–95.

Bhatnagar, T., & Badke-Schaub, P. (2017). Design Thinking and Creative Problem Solving for Undergraduate Engineering Education in India: The Need and Relevance. *International Conference on Research into Design*, 953–967. India: Springer.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In *Assessment and teaching of 21st century skills* (pp. 17–66). Springer.

Botma, Y., Van Rensburg, G. H., Coetzee, I. M., & Heyns, T. (2015). A conceptual framework for educational design at modular level to promote transfer of learning. *Innovations in Education and Teaching International*, *52*(5), 499–509.

Briggs, S. R., & Cheek, J. M. (1986). The role of factor analysis in the development and evaluation of personality scales. *Journal of Personality*, *54*(1), 106–148.

Britton, B. K., & Tesser, A. (1991). Effects of time-management practices on college grades. *Journal of Educational Psychology*, *83*(3), 405.

Brown, J. S., & Duguid, P. (2001). Creativity Versus Structure: A Useful Tension. (cover story). *MIT Sloan Management Review*, *42*(4), 93–94.

Bruner, J. (1962). The conditions of creativity. In *Contemporary approaches to creative thinking: A symposium held at the University of Colorado.* (pp. 1–30). Retrieved from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=bruner+1962+creativity&btnG=&oq=Bruner+1962

Candy, L. (2013). Evaluating creativity. In *Creativity and Rationale* (pp. 57–84). Springer.

Chadli, S. Y., Idri, A., Ros, J. N., Fernández-Alemán, J. L., de Gea, J. M. C., & Toval, A. (2016). Software project management tools in global software development: A systematic mapping study. *SpringerPlus*, *5*(1), 2006.

Cherry, E., & Latulipe, C. (2014). Quantifying the creativity support of digital tools through the creativity support index. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *21*(4), 21.

Chilana, P. K., Ko, A. J., & Wobbrock, J. (2015). From user-centered to adoption-centered design: A case study of an HCI research innovation becoming a product. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 1749–1758. ACM.

Chiu, M. M. (2008). Effects of argumentation on group micro-creativity: Statistical discourse analyses of algebra students' collaborative problem solving. *Contemporary Educational Psychology*, *33*(3), 382–402. https://doi.org/10.1016/j.cedpsych.2008.05.001

Crilly, N., & Cardoso, C. (2017). Where next for research on fixation, inspiration and creativity in design? *Design Studies*, *50*, 1–38.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334.

Cropley, D. H. (2015). Promoting creativity and innovation in engineering education. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(2), 161.

Csikszentmihalyi, M., & Hunter, J. (2003). Happiness in Everyday Life: The Uses of Experience Sampling. *Journal of Happiness Studies*, *4*(2), 185–199. https://doi.org/10.1023/A:1024409732742

Culén, A. L. (2015). HCI education: Innovation, creativity and design thinking. *International Conferences on Advances in Computer-Human Interactions*, 125–130.

Darini, M., Pazhouhesh, H., & Moshiri, F. (2011). Relationship between employee's innovation (creativity) and time management. *Procedia-Social and Behavioral Sciences*, *25*, 201–213.

deChambeau, A. (2017). The Practice of Being a Student: CoPs and Graduate Student Success. In *Implementing Communities of Practice in Higher Education* (pp. 395–422).

Deterding, S. (2012). Gamification: Designing for motivation. *Interactions*, *19*(4), 14–17.

Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning. In *Technology-enhanced learning* (pp. 3–19). Springer.

D'souza, N., & Dastmalchi, M. R. (2016). Creativity on the move: Exploring little-c (p) and big-C (p) creative events within a multidisciplinary design team process. *Design Studies*, *46*, 6–37.

Dziuban, C. D., & Shirkey, E. C. (1974). When is a correlation matrix appropriate for factor analysis? Some decision rules. *Psychological Bulletin*, *81*(6), 358.

Eccles, J. (1983). *Expectancies, values and academic behaviors: Achievement and achievement motives: Psychological and sociological approaches*. San Francisco: Free man.

Farh, J.-L., Lee, C., & Farh, C. I. (2010). Task conflict and team creativity: A question of how much and when. *Journal of Applied Psychology*, *95*(6), 1173.

Finken, S., Culén, A. L., & Gasparini, A. (2014). *Nurturing creativity: Assemblages in HCI design practices*.

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Frich, J., Biskjaer, M. M., & Dalsgaard, P. (2018). Why HCI and Creativity Research Must Collaborate to Develop New Creativity Support Tools. *Proceedings of the Technology, Mind, and Society*, 10. ACM.

Furnham, A., Batey, M., Booth, T. W., Patel, V., & Lozinskaya, D. (2011). Individual difference predictors of creativity in Art and Science students. *Thinking Skills and Creativity*, *6*(2), 114–121.

Gardner, D. G., & Cummings, L. L. (1988). Activation theory and job. *Research in Organizational Behavior*, *10*, 81–122.

Gehlbach, H., Brown, S. W., Ioannou, A., Boyer, M. A., Hudson, N., Niv-Solomon, A., … Janik, L. (2008). Increasing interest in social studies: Social perspective taking and self-efficacy in stimulating simulations. *Contemporary Educational Psychology*, *33*(4), 894–914. https://doi.org/10.1016/j.cedpsych.2007.11.002

Gero, J., & Kan, J. (2016). Empirical results from measuring design creativity: Use of an augmented coding scheme in protocol analysis. *DS86: Proceedings of The Fourth International Conference on Design Creativity, Georgia Institute of Technology, Atlanta, GA, USA*.

Glăveanu, V. P., Ness, I. J., Wasson, B., & Lubart, T. (2019). Sociocultural Perspectives on Creativity, Learning, and Technology. In *Creativity Under Duress in Education?* (pp. 63–82). Springer.

Gorsuch, R. L. (1983). *Factor Analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hadwin, D. H., Järvelä, S., & Miller, M. (2011). *Handbook of self-regulation of learning and performance*. Taylor & Francis.

Harvey, S. (2014). Creative Synthesis: Exploring the Process of Extraordinary Group Creativity. *Academy of Management Review*, *39*(3), 324–343. https://doi.org/10.5465/amr.2012.0224

Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction*, *19*(4), 319–349.

Heuer, T., & Stein, J. (2019). From HCI to HRI: About Users, Acceptance and Emotions. *International Conference on Human Systems Engineering and Design: Future Trends and Applications*, 149–153. Springer.

Hirst, G., Van Knippenberg, D., & Zhou, J. (2009). A cross-level perspective on employee creativity: Goal orientation, team learning behavior, and individual creativity. *Academy of Management Journal*, *52*(2), 280–293.

Hoffmann, O. (2016). On modeling human-computer co-creativity. In *Knowledge, Information and Creativity Support Systems* (pp. 37–48). Springer.

Horn, D., & Salvendy, G. (2006). Product creativity: Conceptual model, measurement and characteristics. *Theoretical Issues in Ergonomics Science*, *7*(4), 395–412.

Hoskins, S. L., & Van Hooff, J. C. (2005). Motivation and ability: Which students use online learning and what influence does it have on their achievement? *British Journal of Educational Technology*, *36*(2), 177–192.

Hsiao, S.-W., Wang, M.-F., & Chen, C.-W. (2017). Time pressure and creativity in industrial design. *International Journal of Technology and Design Education*, *27*(2), 271–289.

Huang, C. S., Yang, S. J., Chiang, T. H., & Su, A. Y. (2016). Effects of situated mobile learning approach on learning motivation and performance of EFL students. *Journal of Educational Technology & Society*, *19*(1), 263.

Jaarsveld, S., Lachmann, T., & van Leeuwen, C. (2012). Creative reasoning across developmental levels: Convergence and divergence in problem creation. *Intelligence*, *40*(2), 172–188.

Jeon, M., Fiebrink, R., Edmonds, E. A., & Herath, D. (2019). From rituals to magic: Interactive art and HCI of the past, present, and future. *International Journal of Human-Computer Studies*.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151.

Kantosalo, A., & Toivonen, H. (2016). *Modes for Creative Human-Computer Collaboration: Alternating and Task-Divided Co-Creativity*. 8.

Karakaya, A. F., & Demirkan, H. (2015). Collaborative digital environments to enhance the creativity of designers. *Computers in Human Behavior*, *42*, 176–186.

Kaufman, J. C., & Baer, J. (2005). *Creativity across domains: Faces of the muse*. Psychology Press.

Kaufman, J. C., Plucker, J. A., & Russell, C. M. (2012). Identifying and assessing creativity as a component of giftedness. *Journal of Psychoeducational Assessment*, *30*(1), 60–73.

Kim, K. H. (2006). Can We Trust Creativity Tests? A Review of the Torrance Tests of Creative Thinking (TTCT). *Creativity Research Journal*, 13.

Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education*, *14*(1), 23–40. https://doi.org/10.1007/BF03173109

Kurtzberg, T. R., & Amabile, T. M. (2001). From Guilford to creative synergy: Opening the black box of team-level creativity. *Creativity Research Journal*, *13*(3–4), 285–294.

L. Dym, C., Agogino, A., Eris, O., Frey, D., & Leifer, L. (2005). Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education - Washington-*, *94*, 103–120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Lance, C. E., Butts, M. M., & Michels, L. C. (2006). The Sources of Four Commonly Reported Cutoff Criteria: What Did They Really Say? *Organizational Research Methods*, *9*(2), 202–220. https://doi.org/10.1177/1094428105284919

Lew, K. H., Park, J., Lee, K., & Kang, S. (2013). The relationship among creativity thinking ability, creative personality and creative product. *Advanced Science and Technology Letters*, *36*, 58–62.

Linnenbrink-Garcia, L., Pugh, K. J., Koskey, K. L., & Stewart, V. C. (2012). Developing conceptual understanding of natural selection: The role of interest, efficacy, and basic prior knowledge. *The Journal of Experimental Education*, *80*(1), 45–68.

Loiacono, E. T., Watson, R. T., & Goodhue, D. L. (2002). WebQual: A measure of website quality. *Marketing Theory and Applications*, *13*(3), 432–438.

Losada, M. (1999). The complex dynamics of high performance teams. *Mathematical and Computer Modelling*, *30*(9–10), 179–192.

Mamykina, L., Candy, L., & Edmonds, E. (2002). Collaborative creativity. *Communications of the ACM*, *45*(10), 96–99.

McCrickard, D. S., Wahid, S., Branham, S. M., & Harrison, S. (2013). Achieving both creativity and rationale: Reuse in design with images and claims. In *Creativity and Rationale* (pp. 105–119). Springer.

McKenna, H. P., & Chauncey, S. A. (2015). Exploring a creativity assessment technique for use in 21st century learning, library, & instructional collaborations. *8th International Conference of Education, Research and Innovation (ICERi2015)*, 1713–1717.

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220.

Meneely, J., & Portillo, M. (2005). The adaptable mind in design: Relating personality, cognitive style, and creative performance. *Creativity Research Journal*, *17*(2–3), 155–166.

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures: Issues and applications*. Sage Publications.

Niazi, M., Mahmood, S., Alshayeb, M., Riaz, M. R., Faisal, K., & Cerpa, N. (2013). Challenges of project management in Global Software Development: Initial results. *2013 Science and Information Conference*, 202–206. IEEE.

O'connor, B. P. (2000). SPSS and SAS programs for determining the number of components using parallel analysis and Velicer's MAP test. *Behavior Research Methods, Instruments, & Computers*, *32*(3), 396–402.

Ohly, S., & Fritz, C. (2010). Work characteristics, challenge appraisal, creativity, and proactive behavior: A multi-level study. *Journal of Organizational Behavior*, *31*(4), 543–565.

Onsman, A. (2016). Assessing creativity in a 'New Generation'architecture degree. *Thinking Skills and Creativity*, *19*, 210–218.

Oulasvirta, A., & Hornbæk, K. (2016). Hci research as problem-solving. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 4956–4967. ACM.

Paulus, P. B., & Baruah, J. (2018). Enhancing Creativity in E-Planning: Recommendations From a Collaborative Creativity Perspective. In *New Approaches, Methods, and Tools in Urban E-Planning* (pp. 192–222). IGI Global.

Paulus, P. B., & Nijstad, B. A. (2003). *Group creativity: Innovation through collaboration*. Oxford University Press.

Pearson, R. H., & Mundform, D. J. (2010). Recommended Sample Size for Conducting Exploratory Factor Analysis on Dichotomous Data. *Journal of Modern Applied Statistical Methods*, *9*(2), 359–368. https://doi.org/10.22237/jmasm/1288584240

Peters, D., Calvo, R. A., & Ryan, R. M. (2018). Designing for motivation, engagement and wellbeing in digital experience. *Frontiers in Psychology*, *9*, 797.

Pett, M. A., Lackey, N. R., & Sullivan, J. J. (2003). *Making sense of factor analysis: The use of factor analysis for instrument development in health care research*. Sage.

Pierce, J., Sengers, P., Hirsch, T., Jenkins, T., Gaver, W., & DiSalvo, C. (2015). Expanding and refining design and criticality in HCI. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 2083–2092. ACM.

Pintrich, P. R. (2004). A Conceptual Framework for Assessing Motivation and Self-Regulated Learning in College Students. *Educational Psychology Review*, *16*(4), 385–407. https://doi.org/10.1007/s10648-004-0006-x

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist*, *39*(2), 83–96.

Prem, R., Ohly, S., Kubicek, B., & Korunka, C. (2017). Thriving on challenge stressors? Exploring time pressure and learning demands as antecedents of thriving at work. *Journal of Organizational Behavior*, *38*(1), 108–123. https://doi.org/10.1002/job.2115

Reise, S. P., Waller, N. G., & Comrey, A. L. (2000). Factor analysis and scale revision. *Psychological Assessment*, *12*(3), 287.

Renninger, K. A., Hidi, S., Krapp, A., & Renninger, A. (2014). *The role of interest in learning and development*. Psychology Press.

Renzulli, J. S. (2002). Emerging conceptions of giftedness: Building a bridge to the new century. *Exceptionality*, *10*(2), 67–75.

Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan*, *42*(7), 305–310.

Romero, M., & Barberà, E. (2012). Computer-based creative collaboration in online learning. *International Conference on Web-Based Learning*, 330–336. Springer.

Runco, M. A. (2007). A hierarchical framework for the study of creativity. *New Horizons in Education*, *55*(3), 1–9.

Runco, M. A., Walczyk, J. J., Acar, S., Cowger, E. L., Simundson, M., & Tripp, S. (2014). The incremental validity of a short form of the Ideational Behavior Scale and usefulness of distractor, contraindicative, and lie scales. *The Journal of Creative Behavior*, *48*(3), 185–197.

Sanches, P., Janson, A., Karpashevich, P., Nadal, C., Qu, C., Daudén Roquet, C., … Höök, K. (2019). HCI and Affective Health: Taking stock of a decade of studies and charting future research directions. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 245. ACM.

Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, *3*(2), 81.

Scott, T. J. (2015). Distributed Affect As a Framework for Understanding Creative Collaboration. *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition*, 335–336. https://doi.org/10.1145/2757226.2764768

Shneiderman, B. (2007). Creativity support tools: Accelerating discovery and innovation. *Communications of the ACM*, *50*(12), 20–32.

Shneiderman, B., Fischer, G., Czerwinski, M., Resnick, M., Myers, B., Candy, L., … Terry, M. (2006). Creativity Support Tools: Report From a U.S. National Science Foundation Sponsored Workshop. *International Journal of Human-*

Computer Interaction, *20*(2), 61–77. https://doi.org/10.1207/s15327590ijhc2002_1

Stephanidis, C. C., Salvendy, G., Antona, M. of the G. M., Chen, J. Y. C., Dong, J., Duffy, V. G., … Zhou, J. (2019). Seven HCI Grand Challenges. *International Journal of Human–Computer Interaction*, *35*(14), 1229–1269. https://doi.org/10.1080/10447318.2019.1619259

Sternberg, R. J. (2005). Creativity or creativities? *International Journal of Human-Computer Studies*, *63*(4), 370–382. https://doi.org/10.1016/j.ijhcs.2005.04.003

Stoeger, H., & Ziegler, A. (2008). Evaluation of a classroom based training to improve self-regulation in time management tasks during homework activities with fourth graders. *Metacognition and Learning*, *3*(3), 207–230. https://doi.org/10.1007/s11409-008-9027-z

Talone, A. B., Basavaraj, P., & Wisniewski, P. J. (2017). Enhancing Human-Computer Interaction and User Experience Education through a Hybrid Approach to Experiential Learning. *Proceedings of the 18th Annual Conference on Information Technology Education*, 83–88. ACM.

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* American Psychological Association.

Torrance, E. P. (1966). *Torrance Tests of Creative Thinking: Normstechnical Manual: Research Ed. : Verbal Tests, Forms A and B : Figural Tests, Forms A and B. Flere materialer*. Retrieved from https://books.google.com.cy/books?id=_4dUYAAACAAJ

Valiente, C., Swanson, J., & Eisenberg, N. (2012). Linking Students' Emotions and Academic Achievement: When and Why Emotions Matter. *Child Development Perspectives*, *6*(2), 129–135. https://doi.org/10.1111/j.1750-8606.2011.00192.x

Vyas, D., Heylen, D., Nijholt, A., & Van Der Veer, G. (2009). Collaborative practices that support creativity in design. In *ECSCW 2009* (pp. 151–170). Springer.

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children*, *23*(3), 34–41.

Wagner, D. L. (2017). Mixing Methods: Creative Collaboration in Mobile Moviemaking. *International Journal of Innovation*, *3*(2), 13.

WEF. (2016). *New vision for education: Fostering social and emotional learning through technology*. World Economic Forum Geneva, Switzerland.

Wentzel, K. R., & Miele, D. B. (2009). *Handbook of motivation at school*. Routledge.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68–81.

Wishart, J., & Eagle, S. (2012). The Development of a Scale to Assess Creative Collaboration via Online Tools. *New Horizons in Web Based Learning*, 320–329. https://doi.org/10.1007/978-3-662-43454-3_33

Wishart, J., Eagle, S., Romero, M., Barberà, E., Järvelä, S., Hyvönen, P., & Vuopala, E. (2011). *CoCreat Research Plan. Internal report of the CoCreat project*.

Wolters, C. A., Won, S., & Hussain, M. (2017). Examining the relations of time management and procrastination within a model of self-regulated learning. *Metacognition and Learning*, *12*(3), 381–399.

Wong, W., Kotze, P., Read, J., Bannon, L., & Hvannberg, E. (2007). Inventivity in HCI Education: Lessons from Limerick. *Creativity: Experiencing to Educate and Design-Proceedings of the HCI Educators 2007*, 29–30.

Wood, N. D., Akloubou Gnonhosou, D. C., & Bowling, J. W. (2015). Combining parallel and exploratory factor analysis in identifying relationship scales in secondary data. *Marriage & Family Review*, *51*(5), 385–395.

Yuan, F., & Zhou, J. (2015). Effects of cultural power distance on group creativity and individual group member creativity. *Journal of Organizational Behavior*, *36*(7), 990–1007.

Zaharias, P. (2009). Usability in the context of e-learning: A framework augmenting 'traditional'usability constructs with instructional design and motivation to learn. *International Journal of Technology and Human Interaction (IJTHI)*, *5*(4), 37–59.

Zampetakis, L. A., Bouranta, N., & Moustakis, V. S. (2010). On the relationship between individual creativity and time management. *Thinking Skills and Creativity*, *5*(1), 23–32. https://doi.org/10.1016/j.tsc.2009.12.001

Zeng, L., Salvendy, G., & Zhang, M. (2009). Factor structure of web site creativity. *Computers in Human Behavior*, *25*(2), 568–577.

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science*, *21*(2), 179–217.

Zimmerman, J., & Forlizzi, J. (2014). Research through design in HCI. In *Ways of Knowing in HCI* (pp. 167–189). Springer.

Zurita, G., Baloian, N., Pino, J. A., & Boghosian, M. (2016). Introducing a Collaborative Tool Supporting a Learning Activity Involving Creativity with Rotation of Group Members. *J. UCS*, *22*(10), 1360–1379.

Appendix A

Table A1

ASCC Principal Axis Analysis with Oblimin Rotation extracted Eigenvalues, Mean & Percentile Data Eigenvalues

Factor	Extraction Sums of Squared Loadings			Rotation Sums of Sq Loadings[a]
	Total	% of Variance	Cumulative %	Total
1	9,084	36,336	36,336	8,210
2	1,672	6,687	43,023	4,002
3	1,065	4,260	47,283	5,042

Table A2

Principal Axis Factor Analysis with Oblimin Rotation – factor labels & items, loadings, deletions and retentions

		Factor		
		1	2	3
1.	Our group worked together well	,930	-,126	
2.	Everyone in our group was engaged in the task	,850	-,110	
3.	My classmates/colleagues in my group trust each other	,813		
4.	Everyone in our group was interested in the task	,787		,106
5.	Everyone in my group wanted to make a successful product	,733	,113	
6.	We had a feeling of belonging together	,642		
7.	We were all able to express our ideas, even controversial ones freely	,602	,313	-,152
8.	We were able to share and discuss our early ideas with each other	,586	,355	
9.	We understood each other's viewpoints at the start of the project	,579		
10.	Our group had the necessary knowledge to be able to complete our task	,498	-,136	,317
11.	I had a good idea of what the others in my group knew that is relevant to this activity	,486	,167	,130
12.	We weren't always certain about how to carry out the task which led us to explore different possibilities		,630	
13.	We sometimes disagreed but we discussed our different points of view	,196	,594	
14.	My group were pressured to complete in time		,492	
15.	We were able to share information with the other group members formally e.g. in a wiki or shared document		,475	,184
16.	We could see or find out what other people knew or were thinking about. For example, we could draw, write or build things on the computer that the other group members could see and/or read	,226	,447	,189
17.	We were able to chat informally with the other group members via text or social networking	,267	,427	
18.	My group generated different and novel ideas in response to the task	,331	,343	,305
19.	We went beyond the set task			,683
20.	Our group organized our time for learning well	,405	-,257	,610
21.	I organized my time for learning well			,582
22.	The set task/activity enabled us to express our emotions		,146	,427
23.	Between us we used a lot of imagination	,283	,223	,426
24.	We played with ideas while we were working on the project	,245	,271	,302
25.	We were able to video conference/talk face to face with the other group members		,273	,280

Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Table A3

Reliability Statistics for the ASCC Subscales (N = 236)

	Cronbach's alpha	Mean inter-item correlations	SD of inter-item correlations	N of items
Factor 1	,924	,695	0,01	11
Updated*	,893*	,654*	0,00*	9*
Factor 2	,778	,505	0,01	7
Factor 3	,758	,529	0,01	5

* following deletion of items 1and 3

Table A4

Scale dimensions, descriptions and individual items

Dimension 1	**Synergistic Social Collaboration**	**Theoretical Origin**
9-item subscale that measures social collaborative learning and the conceptual variables of interest and emotional factors such as belonging, mutuality and trust		
Group interest in the task	1. Everyone in our group was interested in the task.	Interest
Trust between participants	2. My classmates/colleagues in my group trust each other.	Social Collaborative Learning
Orientation towards the task success	3. Everyone in my group wanted to make a successful product.	Interest
Safe atmosphere	4. We had a feeling of belonging together.	Social Collaborative Learning
Communication	5. We were all able to express our ideas, even controversial ones freely.	Creativity
Discussion of early ideas	6. We were able to share and discuss our early ideas with each other.	Creative Collaboration
Level of collaboration	7. We understood another's viewpoints at the start of the project.	Social Collaborative Learning
Adequate knowledge base	8. Our group had the necessary knowledge to be able to complete our task.	Social Collaborative Learning
Shared knowledge and goals	9. I had a good idea of what the others in my group knew that is relevant to this activity.	Interest

Dimension 2	**Distributed Creativity**	**Theoretical Origin**
7-item subscale that measures collective divergent thinking and externalization, the degree of tension and the perceived co-presence in distant teams		
Problem boundaries stretched or broken	10. We weren't always certain about how to carry out the task which led us to explore different possibilities.	Creativity
A degree of disagreement or tension	11. We sometimes disagreed but we discussed our different points of view.	Creativity
Group-based time pressure	12. My group were pressured to complete in time.	Time Pressure
Degree of co-presence (formally - text based)	13. We were able to share information with the other group members formally e.g. in a wiki or shared document.	Interest
Possibilities for externalizing representations	14. We could see or find out what other people knew or were thinking about. For example, we could draw, write or build things on the computer that the other group members could see and/or read	Creativity
Degree of co-presence (informally - SN)	15. We were able to chat informally with the other group members via text or social networking.	Interest
Level of divergent thinking	16. My group generated different and novel ideas in response to the task.	Creativity

Dimension 3	**Time Regulation and Achievement**	**Theoretical Origin**
5-item subscale that measures the degree of individual and collective time-management as components of learning regulation that link to achievement		
Stretching boundaries	17. We went beyond the set task.	Creativity
Group-level time management	18. Our group organized our time for learning well.	Time Management
Individual time management	19. I organized my time for learning well	Time Management
Emotional expression	20. The set task/activity enabled us to express our emotions.	Social Collaborative Achievement
Level of imagination	21. Between us we used a lot of imagination	Creativity

Table A5

Inter-item correlation matrix for subscale 1: 'Synergistic Social Collaboration' subscale

	Adequate knowledge base	Comm.	Discussion of early ideas	Group interest	Shared knowledge & goals	Task success	Trust	Safe atmosphere	Level of collaboration
Adequate knowledge base	1,000	,295	,460	,550	,421	,462	,440	,458	,380
Communication	,295	1,000	,608	,463	,467	,481	,498	,359	,460
Discussion of early ideas	,460	,608	1,000	,558	,548	,587	,466	,527	,391
Group interest	,550	,463	,558	1,000	,412	,664	,572	,539	,451
Shared knowledge & goals	,421	,467	,548	,412	1,000	,500	,477	,401	,427
Task success	,462	,481	,587	,664	,500	1,000	,563	,552	,475
Trust	,440	,498	,466	,572	,477	,563	1,000	,573	,541
Safe atmosphere	,458	,359	,527	,539	,401	,552	,573	1,000	,380
Level of collaboration	,380	,460	,391	,451	,427	,475	,541	,380	1,000

Table A6

Inter-item correlation matrix for subscale 2: 'Distributed Creativity'

	Degree of co-presence (formal)	Degree of co-presence (informal-SN)	Degree of disagreement or tension	Level of divergent thinking	Externalizing representations	Group-based time pressure	Problem boundaries stretched
Degree of co-presence (formal)	1,000	,544	,357	,312	,366	,212	,223
Degree of co-presence (informal-SN)	,544	1,000	,354	,392	,473	,140	,233
Degree of disagreement	,357	,354	1,000	,452	,416	,259	,443
Level of divergent thinking	,312	,392	,452	1,000	,476	,275	,316
Externalizing representations	,366	,473	,416	,476	1,000	,169	,257
Group-based time pressure	,212	,140	,259	,275	,169	1,000	,463
Problem boundaries stretched	,223	,233	,443	,316	,257	,463	1,000

Table A7

Inter-item correlation matrix for subscale 3: ‘Time regulation and Achievement’

	Stretching boundaries	Emotional expression	Group-level time management	Individual time management	Level of imagination
Stretching boundaries	1,000	,334	,463	,360	,486
Emotional expression	,334	1,000	,237	,235	,378
Group-level time management	,463	,237	1,000	,636	,435
Individual time management	,360	,235	,636	1,000	,310
Level of imagination	,486	,378	,435	,310	1,000

About the authors

Aekaterini Mavri is a PhD candidate and a full-time member of the special teaching staff at the Department of Multimedia and Graphic Arts at the Cyprus University of Technology. Her research focusses on the role of cross-organizational Communities of Practice on learning in the Design and relevant fields in Higher Education.

Andri Ioannou is an Assistant Professor at the Department of Multimedia and Graphic Arts and Head of the Cyprus Interaction Lab at the Cyprus University of Technology. She is also the Leader of the Interactive Media and Education/Edutainment research group at the Research Center on Interactive Media, Smart Systems and Emerging Technologies (RISE). In her work, she aims to understand the significant supportive and mediating role of technology in promoting learning, communication & collaboration, and social change in varied circumstances and contexts.

Fernando Loizides is a Lecturer (Assistant Prof.) in Computer Science and Informatics at Cardiff University. Fernando's main area of research lies in Information Interaction, HCI and Digital Libraries and Accessibility. He has a computer science background, which he combines with digital library research to investigate how systems can be enhanced by emerging technologies. He has extensive experience in user testing and project management, both within industry and academia.