

A Framework for Understanding Collaborative Creativity in Requirements Engineering: Empirical Validation

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Abstract—Requirements engineering (RE) often needs creativity in a form where interactions among stakeholders are particularly important: *collaborative creativity*. However, few studies have explicitly concentrated on understanding collaborative creativity in RE, resulting in a lack of well-founded advice for practitioners on how to support this aspect of RE. Through an online survey, this paper seeks empirical validation for a framework of factors characterising collaborative creative processes in RE. Within the limits of the validity of the study, the results show support for the utility of the framework: collaborative creativity seems to be a linear function of the mean score to all factors in the framework. Factors can be grouped, and the specific impact of each group on collaboration, value and novelty can be assessed.

I. INTRODUCTION

A typical definition of creativity describes it as “the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e., useful, adaptive to task constraints)” [1]. Further, creativity experts distinguish individual creativity from collaborative (or group) creativity because the latter explicitly relies on interactions within a group to achieve the creative outcome. Mamykina et al. emphasise the importance of this kind of creativity within a contemporary industrial setting [2]: “recent research has begun to paint a more complicated picture of creativity that highlights the importance of social interactions, mentoring, and collaboration in creative work. The importance of analyzing creativity in this more holistic sense is readily apparent when one considers that most creative pursuits in industry involve interdisciplinary teams working together to develop a product that cannot be created by a single individual alone”.

The topic of creativity has received much attention from Requirements Engineering (RE) researchers over the last decade. RE has also been shown to be an inherently creative discipline, as recently summarised by Maiden et al. [3]. In a previous paper [5], the authors suggested that RE is not simply a creative process, but a *collaboratively* creative process. The difference is important to the discipline because individual and collaborative creativity are known to be qualitatively distinct, and thus require different processes, skills, and techniques [4]. They argued that RE activities nearly always require collabora-

tive creativity, because heterogeneous development teams need to create a vision of and to reach a consensus on a new and valuable system they want to build. This implies that the findings in the rest of this paper apply to most RE projects, whether or not innovation is an explicit objective of the project.

This previous work [5] also proposed a list of factors, structured as a conceptual framework, which influence the success of collaboratively creative tasks in the RE process: the “*Collaborative Creativity in Requirements Engineering*” (CCRE) framework. These factors outline what should be considered when tailoring a method, technique or a specific work environment for the collaboratively creative part of RE efforts.

The present paper builds on this previous work by seeking empirical validation of the conceptual framework through a survey that collected 72 responses from RE practitioners.

The paper presents related work (including a brief description of the CCRE framework) in section II. Section III describes the research method. Section IV discloses the results of the survey, while Section V analyses relevant threats. Finally, conclusions and directions for future research are described in Sections VI and VII.

II. RELATED WORK AND CONTRIBUTIONS

A. Collaborative Creativity Framework

The CCRE framework [5] distinguishes between factors relating to the *team* and those related to the *individual*. The team factors are further split into *team context* that surrounds the team, the *team values* that are shared among the team members and the *team structure* that describes how the team is organised internally. These factors can be summarised as:

Team Context

- *Risk Profile*: is a team allowed to take risks?
- *Shared Objective*: is there a clear common objective and is it aligned with the personal objectives of each team member?

- *Time*: is there enough time to share views and build consensus?
- *Culture*: does the culture (the set of habits and values) surrounding the RE team support collaborative creativity?
- *Reward Mechanisms*: is there a policy to reward the group as well as individuals for creative solutions and creative behaviour?

Team Values

- *Trust, Safety, Empathy*: can each member of the collaborative team make mistakes in a supportive environment?
- *Freedom, Tolerance, Openness*: is there a non-judgemental and welcoming atmosphere for conflicting opinions?
- *Fun, Playfulness, Challenge, Flow*: is there an enjoyable and challenging atmosphere that leads a team to “gel”?

Team Structure

- *Team Composition and Roles*: is there a mix of expertise and variety of opinions in the team, balanced with enough homogeneity to ultimately converge?
- *Communication Channels*: is there an adequate set of communication channels and media for the team to use?
- *Processes and Techniques*: is there an adequate set of creativity techniques and processes?
- *Planning*: is the plan suitably flexible to support effective creativity?
- *Facilitation and Leadership*: has leadership moved towards more of a facilitation role?

Individuals

- *Subject Matter Expertise*: is there enough knowledge about the problem within the team?
- *Motivation*: is there enough intrinsic motivation for people to make the project a success?
- *Collaborative creativity skills*:
 - *High Ego-Low Vanity*: individuals must be bold enough to suggest ideas, but also be able to accept one’s ideas are not always useful.
 - *Interdependence-Autonomous*: a balance between interdependence, collective action and power of connection; and individuality, autonomy and trust in one’s own strength.
 - *Trustable Truster*: trust in oneself is complemented by one’s ability to trust others and to be trustworthy to others.
 - *Communicator*: communication is central to collaboration, including strong listening skills, empathy and the ability to make oneself understood.
 - *Learner-Curious*: willingness to learn and having curiosity are key enablers of creativity.
 - *Leader-Follower*: leadership of a collaborative creativity RE session is fluid, so participants require skills in both leadership and in following.
 - *Focus-Defocus*: The ability to remain focused on something specific, but also to be able to defocus and switch rapidly from a detailed view to a high level overview.

B. Other Related Work

According to the recent systematic review by Lemos et al. [6], research in creativity in RE spans over a decade and most-

ly reports on models, techniques, workshops, and tools to enhance creative thinking in RE activities. They report that the majority of studies (60%) focus on the elicitation phase, proposing new solutions and evaluating them. Authors (notably [3], [7]) have also proposed more conceptual works in developing good understandings of characteristics of creativity in this specific domain. Beyond that, general problem solving and collaboration have been common topics in RE research. Further, authors in various fields, including social psychology and management sciences, have been prolific on creativity at work. This literature, of which the reader can find a partial review in [5], forms a heterogeneous body of knowledge to help understand key concepts, issues and trends in creativity research applied to RE. The authors’ previous work consolidated this knowledge into the CCRE framework. In a sense, the CCRE is an abstract translation of this literature review.

A framework for understanding creativity at work, defining characteristics of creative environments, with similar aims to CCRE, has been proposed and empirically evaluated by Amabile et al. [8]. This study is broader in scope and more rigorously validated than CCRE. However, there was a need to both update this 18-year old work to potentially changed innovation conditions and, above all, to specialise the study to RE. Further, while Amabile’s framework studies creativity at an organizational level, CCRE focuses on the project level. The CCRE framework is consequently influenced by Amabile’s framework, but augments it significantly, inspired by more recent literature, in particular literature specific to RE. Consequently, the validation undertaken in this paper differs from Amabile’s work because it validates a significantly different framework on a different target population. The empirical sample used here is primarily made up of requirements engineers and business analysts.

III. RESEARCH METHOD

A. Research Questions

The CCRE framework was based on a literature review and expert opinions, which calls its validity into question. This need for further validation of the framework is the core research question (RQ) of this paper:

RQ: *Is there a positive correlation between the factors in the framework for collaborative creativity (CC) in RE described in Section II [5] and the effective creativity of teams doing RE?*

This question can be refined in various sub-questions:

RQ1: Can factors be grouped in a reduced number of meaningful constructs that can be used to predict CC?

RQ2: What is the most related to CC: the mean of all factors, a weighted sum of the mean of a reduced number of grouped factors, or a weighted sum of a subset of factors?

RQ3: Are there factors that are clearly better, and others clearly worse, for predicting CC?

RQ4: Do factors correlate more with a specific aspect of CC (collaboration, value, novelty)?

B. Survey

A survey, based on an online questionnaire for RE practitioners, was used to assess the validity of the CCRE framework. In this questionnaire participants described a project of their choice in terms of creative factors and creative results. The goal was simply to analyse the correlations between the factors and the results.

Questionnaire Design. The questionnaire¹ consisted of five parts, designed to:

1. Gather general information about the project
2. Evaluate the collaborative creativity on the project
3. Evaluate the presence of team-related factors
4. Evaluate the presence of people-related factors
5. Collect detailed examples and general feedback

The notion of collaborative creativity was evaluated in the questionnaire by five questions. As there is a clear agreement in the literature that creative artefacts are those that are both valuable and novel, we included one question addressing the perceived value, while another one addressed the novelty of the project results. The three remaining questions addressed the collaborative dimension. In our context, collaboration is related to the ability of a set of stakeholders with diverse skills, knowledge and opinions, to come together to an agreed definition of a business problem to be solved and a business solution to that problem. Consequently, we asked about i) the existence of a set of stakeholders having diverse opinions, ii) the existence of open discussions that effectively lead to unexpected results, and iii) the quality of the consensus process: was it rich and constructive, or painful and destructive? The literature on collaborative work offers support for this way of measuring collaboration. In particular, Van den Bossche et al. [9] mention that integrating different perspectives and developing a shared understanding of the problem at hand can be established through rich interaction, interactive discussion, and negotiation.

For measuring the presence of factors, each factor was translated into a single question. This was a minimum, but was also set as a maximum to avoid “survey fatigue”. As many of the factors are quite complex, this translation was often not easy or direct. However, the authors were ultimately convinced that the questions satisfactorily summarised the spirit of each factor. All questions in section 2 and 3 and some of section 4 of the questionnaire were written as statements such as “The main stakeholders regarded the deliverable of this project as novel.” and were answered on a scale from 1 (absolutely false) to 5 (absolutely true). The remaining questions in section 4 were written as statements regarding the skills of the team members and had to be answered on a scale from 1 (not skilled at all) to 5 (very skilled). The last two questions were open, asking for i) examples of situations where the respondent had to deal with a specific factor and ii) any other remark.

Sampling. The survey was sent to the personal networks of all authors of this paper and to several existing lists of RE

practitioners, such as social networks focused on RE. LinkedIn groups such as “Modern Analyst” and “Business Analyst Forum” cumulate many members, most of whom are an ideal target for this study. Several tactics were used to optimise the number of respondents, for example offering high-value training in creativity for teams, and amending the questionnaire formulation during the course of the survey. The survey initially explicitly targeted practitioners of “Requirements Engineering” and “Business Analysis”. However, this vocabulary might be too restrictive and not necessarily shared by the community of practice worldwide. This was changed it to mention “Product and Service Design” in an attempt to yield more answers, but this did not increase the response rate. The last seven completed questionnaires were made under this formulation. There were in total 72 completed questionnaires over a one-year period. A typical message to attract respondents can be found online².

The respondents mostly belonged to organisations of more than 100 people (70.8%), situated in Europe (62.5%), in North and South America (18.1%) or Australia (12.5%). Most projects (>50%) had a duration of more than a year from initiation to going live of the result. There was a balanced distribution of projects in terms of size (as number of persons): about 24% of the projects were small (<5), about 44% were medium-sized (5-20 people), while about 32% were large (>20). People from the same company or project were not specifically asked to answer the survey, but neither was this prohibited. The survey did not ask for the company and project name so cannot guarantee duplicate answers for a single project. However, email addresses from the respondents suggest that this was not frequently the case.

Analysis approach. To address RQ1, a descriptive analysis of the factors was undertaken by applying Principal Component Analysis (PCA). PCA identified and grouped relevant factors into conceptual constructs (principal components), each measuring one meaningful concept. To address other RQs, correlation and linear regression analyses were used to examine the correlations between the factors, the identified principal components and collaborative creativity outcomes. Correlations between all factors, principal components and the three components of collaborative creativity (collaboration, novelty, value) were also examined.

The two first authors generated statistics analyses using SPSS v22 as well as “R” software: each author choosing their preferred tool. Within this paper, the word ‘factor’ is used in a general sense, not in the strict statistical sense used in Factor Analysis and Principal Component Analysis. The factors in this paper match those proposed in the CCRE framework and are included in the survey. The identified groups of factors are referred to as principal components and are named specifically in section IV.

Finally, the answers to open questions are examined, coding their content to identify the most frequently cited factors

¹ The questionnaire can be seen as it was presented to participants at <http://bit.ly/CCRESurvey>.

² <http://bit.ly/linkedinCCRE>

and their impact, as well as potential missing or inappropriate factors. The results of this analysis are provided in Section IV.

IV. RESULTS

A. Descriptive Analysis

In the section 2 of the questionnaire, before questions about factors, participants were asked to describe the level of collaborative creativity of their project. Respondents described an interesting variety of projects in terms of Collaborative Creativity results, though slightly preferring to report on successes than failures. Three of the four indicators of CC had a mean score of around 3.5 and a median of 4, as shown in Figure 1.

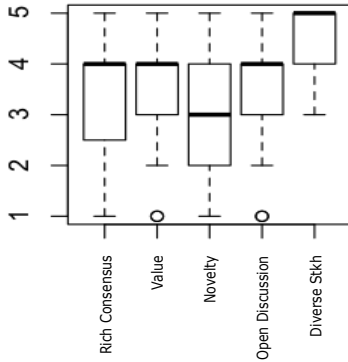


Figure 1: Measures of collaborative creativity in the survey

A crucial point is that the respondents validated the assumption that requirements work calls for collaborative creativity, whether or not there is a specific intention to innovate. Indeed, in the great majority of cases, the project had to deal with diverse stakeholders having various opinions that ultimately had to converge (as illustrated by the box on the right of Figure 1 (Figure 1)).

The factors follow a similar pattern: a smooth distribution slightly skewed upwards. In particular the individual skills were not given low values: in general people had the impression that they were surrounded by very capable colleagues.

B. Principal Component Analysis (RQ1)

Two Principal Component Analyses (PCAs) were repeated on individual and team factors separately. This technique was used to see how the factors could be grouped in a reduced number of components (the Principal Components, PC) that summarise the factors sufficiently well. Standard statistical steps were successfully taken to check that the CCRE framework factors were sufficiently correlated to proceed with PCA. Components were identified based on their ability to sufficiently explain the variance of the original set of factors, both individually and collectively. Other measures were taken to confirm the reliability of the selected components. The most relevant statistical numbers concerning PCA are given below and can be analysed in greater detail by downloading additional material at <http://bit.ly/CCREAnalysis>.

- MSA ratio = {5.25; 9.31}
- Bartlett's test: all p-values < 0.0001
- Overall KMO = {8.54; 7.59}
- Eigenvalue > 1 for each component
- Total variance explained > 60%
- Cronbach's alpha = {.73; .85; .77; .78; .58}

Grouping of Individual Factors. The PCA reveals two groups of individual factors. Those groups are very close to the intuitive separation made in the original CCRE framework: it separates "CCRE Skills" from the rest (motivation and subject matter expertise) (as described in Section II.A). However, the PCA separated the "balance between autonomy and interdependence" factor from the CCRE Skills, which was not as expected. Given those results, the PCAs were renamed as "Pragmatic Skills" and "Relational Skills".

Grouping of Team Factors. The PCA reveals three groups of team factors. The grouping seems intuitively reasonable, even though it does not correspond to the grouping in the original framework. The three groups were named i) Adapted Project Management, ii) Collaborative Values and iii) Creative Focus.

Un-grouped factors. "Culture" and "Reward Mechanism" were excluded from principal components as a result of the PCA analysis. This is because most of the variance in the original set of factors could be explained without taking those into account. Figure 2 shows the mapping from the initial framework to the Principal Components.

C. Relations between Collaborative Creativity and Factors (RQ2 and RQ3)

Based on the arithmetic mean, a composite score was computed to summarise the above factors for each principal component. Additionally, the measures of creativity were grouped into several composite scores:

- Creativity = Mean (Novelty, Value)
- Collaboration = Mean (Rich Discussion, Constructive Consensus)
- Collaborative Creativity (CC) = Mean (Creativity, Collaboration)

Additionally, all of the factors were averaged into the global "Factors" score.

Linear Regression tests were conducted to determine the extent to which CC could be predicted by a formula in the style "CC = B0 + B1*F1 + B2*F2...", with Fi representing the score to Factor i, or the average score of an aggregation of factors, and Bi a coefficient to be determined by the regression. This regression can denoted "CC~F1+F2+...".

Three kinds of formulae were utilised; the first had only one coefficient B1, with F1 being the average score of all factors. The second set of formulae assigned a coefficient to each principal component (Fi is the average score of PCi); and the third assigned a coefficient to each single factor.

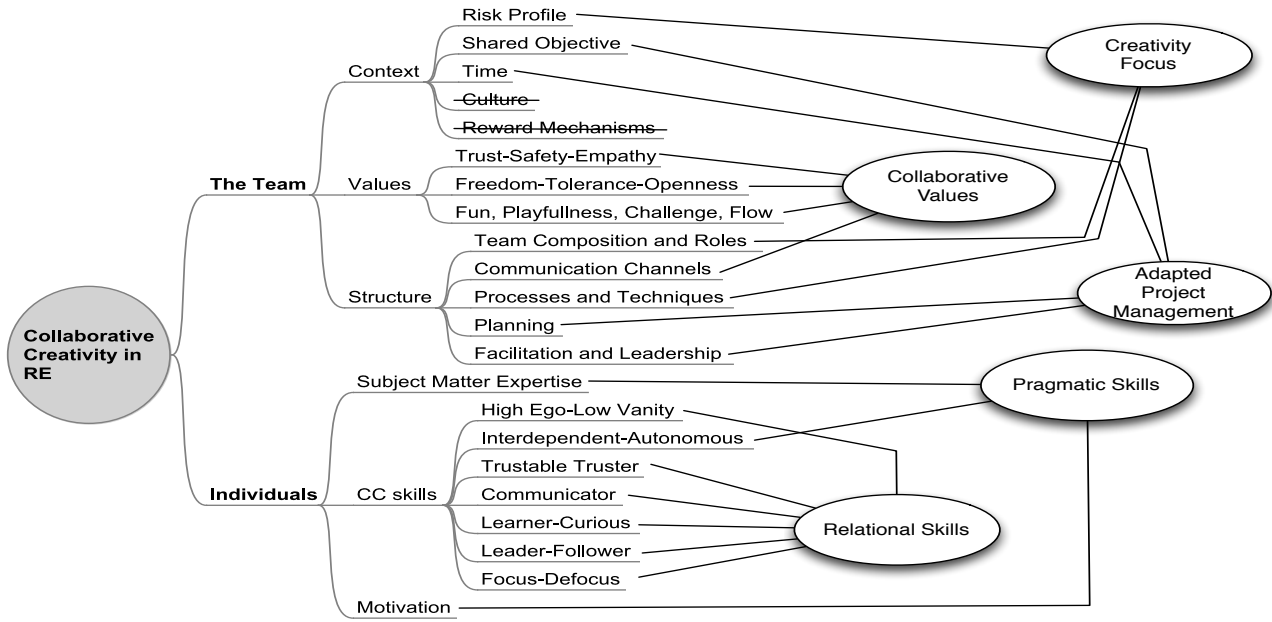


Figure 2: Mapping between the initial Framework and the Principal Components

The first and simplest formula achieved the most significant results. As Table 1 indicates, CC evolves proportionally to the mean of all factors, which could not statistically occur by chance (** and *** significance indicate $p\text{-value} < 0,001$ and $p\text{-value} < 0,0001$ respectively). “Adjusted R2” (R-squared) and “Std Residual” (standard residual) indicate the precision of the prediction. For a strong prediction power, R-Squared should be close to one, and the standard residual should be close to zero. While being the best of all models tested, the values still indicate quite low prediction power: only a part of the variance in CC can be explained by the CCRE framework. However, this is not unexpected, since collaborative creativity is a very complex social phenomenon which by nature is hardly predictable. Amabile’s study [8] displays higher values, but still in the lower range (between .05 and .44) for the work environment scales in her framework.

TABLE 1. LINEAR REGRESSION: CC~FACTORS

Formula	B0	B1	Significance	Adj R2	Std Residual
CC ~Factors	1,18	.67	**/**	.30	.61

The second model, with a coefficient for each principal component, did not yield results of any significance. A step-wise regression towards a minimally significant model (by systematically removing the least significant component one at a time until no insignificant result remains) lead to the inclusion of only two principal components: Relational Skills and Creative Focus. The results are shown in Table 2.

TABLE 2: CC~RELATIONS+CREATIVE FOCUS

Formula	B0	B1	B2	Sig	Adj R2	Std Residual
CC ~ Relations+ Creative Focus	1,32	.46	.19	**/**	.27	.63

The third model, assigning a degree of freedom for each factor, also yielded results with very low significance, from which no strong conclusions could be drawn.

As shown in Table 3, the analysis of the link between each individual principal components and CC indicates a statistically significant correlation in terms of covariance ($p < 0,001$ or lower), but again, the variance explained is quite low.

TABLE 3: CC~PCs

CC~PC	B0	B1	Significance	Adjusted R2	Std Residual
Pragmatic	2,13	.34	**	.9	.70
Relation	1,69	.53	***	.24	.65
Coll Values	2,16	.37	***	.16	.68
Crea Focus	2,41	.31	**	.11	.70
Adpt Mgmt	2,36	.34	***	.16	.68
AVG	2,15	.38		.152	.682

These results indicate that there is a significant correlation between CC and the factors in the framework. However, the factors are only able to predict a limited part of the variation in CC: around 30%. This suggests the need to remain cautious when working with CC, since it is a complex phenomenon that is not easily predicted.

The factors in relevant principal components can be grouped, but those groups are not very useful to predict CC on their own. This seems to indicate that any simplification by grouping or modification to the list is detrimental to the prediction of collaborative creativity. The above provides important insights concerning RQ1 and RQ2.

As each PC is examined separately, Relational skills are twice shown to have the most influence on CC (in both the stepwise and individual linear regression tests). Creative focus, Project Management and Collaborative values are indicated once each, whilst Pragmatic skills seem slightly less influential.

For the excluded factors, the influence of local culture and the existence of a collective reward scheme were both indicating low correlation with CC. A closer analysis seemed to indicate the existence of a relation between the region of the project and the facilitator effect of the culture. This could be due to the small number of responses outside Europe, or reflect a real effect of the culture of the project.

Consequently, as an answer to RQ3, relational skills seem to be the most influential factors in the CCRE framework. More research is needed to understand the influence of culture and collective reward on CC.

D. Heat Maps (RQ4)

In an attempt to answer RQ4, heat maps were used to understand if the factors had an influence on specific parts of CC (collaboration, novelty, value). A heat map is a graphical representation of data where the individual values contained in a matrix are represented as colors. In this case, a two-dimensional space is defined, with regions where values are high or low depicted as coloured oval shapes, thus defining “hot” and “cold” regions. Firstly a comparison was made on the effect of the factors on collaboration versus creativity. Secondly creativity was “split” to compare the effect of the factors on the constituents of creativity (value and novelty).

The first map (Figure 3) shows that records with a high mean of factors tend to have both high Collaboration and high Creativity. Reversely, those that have a low mean of factors tend to be in the region of low collaboration and creativity. It seems to follow that, when averaged, the factors do not have a stronger influence on either collaboration or creativity, but that they influence both together.

The influence of each PC on novelty versus value was analysed, by creating one heat map per PC. **Figure 4** superimposes the significant hot and cold zones of all of these maps onto a single diagram, giving an indication of the influence of each PC on both Novelty and Value. The oval shape indicates where the highest (plain line, orange) or lowest (dashed line, blue) means of the PC were found on a novelty/value map. The original maps can be consulted online at <http://bit.ly/CCREAnalysis>.

As indicated by the plain orange oval shape on the top left of **Figure 4**, the responses with a high score to Pragmatic Skills tend to be quite valuable, but not really novel. This suggests a positive correlation of pragmatic skills with value, and negative with novelty.

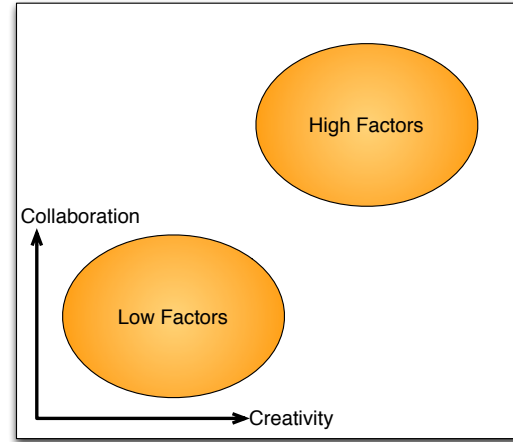


Figure 3: Influence of factors on Collaboration and Creativity

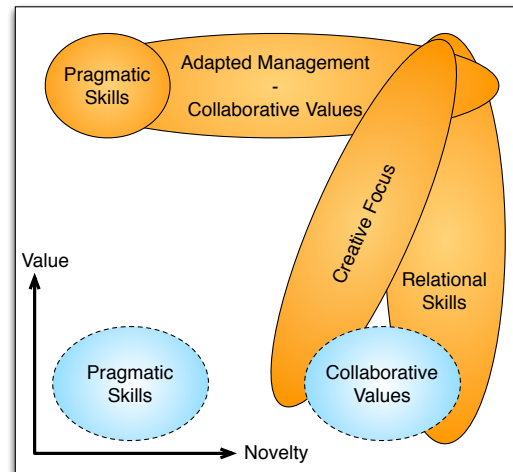


Figure 4: Influence of each PC on Value and Novelty

This echoes other studies that indicate the importance of ignorance in creativity in RE [10], so this result could have been expected. However, the lowest means of this PC, as indicated by the dashed blue oval on **Figure 4**, are located in regions of low-neutral novelty and value; indicating that without pragmatic skills, there is no creativity.

The highest mean of Relational Skills is located in the high novelty regions, in different bands of value, indicating its closer relationship with Novelty.

There is a stronger relation of Adapted Project Management and Collaborative Values with value as an outcome of the project. A surprising result is that teams with low Collaborative Values may have produced quite novel results with low value.

Creative Focus seems to be related to both novelty and value, but the presence of high Creative Focus in the middle-range values indicates that this component is not sufficient on its own to ensure creativity.

In conclusion, the various PCs do have a different impact on the components of creativity. None of them is able to produce by itself results that are both novel and useful/valuable

(no oval shape is on the upper right corner and only there). This suggests that their ‘smooth’ combination is needed to allow teams to create at their best.

E. Open Questions

In their answers to open questions, the participants mentioned most of the 21 factors in the CCRE framework. The factors not mentioned were all in the individual skills group. It seems that people are not aware, not convinced, or not willing to talk about the role of some individual characteristics in CC. The ability to switch from leader to follower, to balance ego and vanity, to balance interdependence and autonomy were virtually absent from the open answers, while the analysis shows that they are highly influential (members of the “Relational Skills” component).

The most cited factors were:

- **Communication (8):** Explaining ideas again and again, sending minutes, using consistent terminology, using models and visuals, encouraging honest discussions and open dialogue, listening to all and conducting review sessions are various signs of communication focus that were noted.
- **Subject Matter Expertise (8):** The need to involve the right stakeholders, as well as their level of expertise, was frequently mentioned as crucial, enabling the group to think beyond the obvious.
- **Techniques (7):** People frequently mentioned the techniques they used, including general techniques (such as prototyping, scenarios and workshops) but also specific creativity techniques (including Six-Sigma, Cognitive Edge and many others).
- **Roles (7):** People insisted on the need for a distributed responsibility, empowered stakeholders and high levels of participation.
- **Trust-Empathy-Safety (7):** Taking weaker stakeholders into account, avoiding destructive criticism, respect, collaboration spirit and well-being were all mentioned.
- **Motivation (6):** The love of the job and the intrinsic motivation were frequently cited.
- The next most cited factors were: openness (4); the ability to take risks (4); the existence of adequate communication channels (4); the (lack of) resources (time, money) (3); Culture (2); Fun (2); Planning (Agile, 2); Diversity, Facilitation, Curious-Learner and Reward Mechanism.

V. THREATS TO VALIDITY

Construct Validity: while all measures were carefully selected and, as far as possible based on literature, it is clear that the concepts analysed by the study are by their nature difficult to measure. The precision of the study is consequently quite low, which is to be expected in this domain. In particular, the survey is based on the respondent’s own perceptions. It could be argued that this is less objective than having a group of experts assessing the creative value of the results produced by each project as well as the factors for creativity during the project. This would be impossible to achieve in this study, but in addition, Amabile argues that objective measurement is not

particularly desirable in this case. Indeed, she shows that *perceptions* of work environment have more impact than the real work conditions themselves on people and groups behaviours [8]. So whether or not there actually is an organisational encouragement for taking risks (for example), what matters is that the respondent perceives this encouragement. There must however be some correlation between the work reality and the respondent’s perception, in order to give actionable insights to practitioners. This study was not able to assess this correlation, since it did not record specific company or project details. Hence it was not possible to crosscheck respondents’ opinions for consistency, affecting the validity of the study.

Internal Validity: Answers to the open questions were used to collect other factors: potentially missed elements that could explain variance in the outcome outside the framework. The analysis of these did not identify such missing or external factors. Each questionnaire described a specific environment of which only partial information was collected: given the low values for R-squared, other factors influencing CC were also at play.

External Validity: A positive aspect of the sampling strategy was the diverse sample, leading to a much better external validity than if the survey had concentrated on one or two companies. Indeed, while dominated by European projects, the sample can be considered quite diverse in all other dimensions, and is potentially representative of a large number of industrial situations.

Conclusion Validity: The reasonable size of the sample (N=72) lead to results with high statistical significance. The low R-squared values indicate that the model only explains a part of the variance in the outcome. The unpredictable nature of creativity partly explains this low prediction power, but some important factors may still be still missing from the framework. In both cases, this suggests that the framework can be used, but with caution.

VI. CONCLUSIONS

Within the limits of the validity of the studies, empirical evidence indicates that the CCRE framework can be a useful tool to understand and facilitate collaborative creativity in Requirements Engineering. Indeed, collaborative creativity scores and average factor scores evolve in the same directions. However, the results also underline that collaborative creativity is not easily predicted, suggesting caution when studying or facilitating such processes. The study has shown that grouping of factors is possible, into 5 groups that are relatively close to the original groups suggested. Some groups seemed to be more important than others, in particular Relational Skills. Those factors were not in the scope of the study on this topic by Amabile. Various groups of factors, such as Creative Focus, Adapted Project Management and Collaborative Values were shown to have different impacts on value and novelty. Importantly, no factor (or group of factors) is sufficient to ensure both high value and novelty, which supports the idea that all of the factors are important.

Providing a holistic view on elements influencing group creativity in RE is an important step for research in this do-

main. In particular, using the CCRE framework, researchers may now assess any creativity support initiative for RE. Open questions also revealed that practitioners were only partly aware of what makes an effective RE team, supporting the idea that such a framework will be useful to them.

VII. FUTURE WORK

The validation proposed here was a significant step. However, there remains work to be done in this direction. New studies, in particular, could hope to bring additions to the framework, different approaches could lead to a better explanation of the variability in CC performances in RE. The field probably also requires more qualitative approaches, such as face-to-face interviews, a deep case study or ethnographic research in order to get an in-depth understanding of the “how” and “why” behind the collaborative creativity factors. This kind of study could also be useful to understand the influence of Culture on collaborative creativity. More research is also needed to understand the influence of the various kinds of creativity [11] on CC support.

To facilitate reuse of this work by anyone, all data and analysis is accessible online at <http://bit.ly/CCREAnalysis>.

As a more generic message to the research community, the above findings suggest that research should perhaps stop focusing solely on creativity *techniques* (only one factor out of 19) and encompass a broader view of creativity support in RE.

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