

Fostering **creativity** in **learning**  
through digital **games**



*Creative Emotional Reasoning Computational Tools Fostering Co-Creativity in Learning Processes*

[www.c2learn.eu](http://www.c2learn.eu)

# USER PROFILING AND BEHAVIOUR DETECTION

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**Dissemination level:** Confidential

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## EXECUTIVE SUMMARY

### *C<sup>2</sup>Learn at a glance*

C<sup>2</sup>Learn ([www.c2learn.eu](http://www.c2learn.eu)) is a three-year research project supported by the European Commission through the Seventh Framework Programme (FP7), in the theme of Information and Communications Technologies (ICT) and particularly in the area of Technology-Enhanced Learning (TEL) (FP7 grant agreement no 318480). The project started on 1<sup>st</sup> November 2012 with the aim to shed new light on, and propose and test concrete ways in which our current understanding of creativity in education and creative thinking, on the one hand, and technology-enhanced learning tools and digital games, on the other hand, can be fruitfully combined to provide young learners and their teachers with innovative opportunities for creative learning. The project designs an innovative digital gaming and social networking environment incorporating diverse computational tools, the use of which can foster co-creativity in learning processes in the context of both formal and informal educational settings. The C<sup>2</sup>Learn environment is envisioned as an open-world 'sandbox' (non-linear) virtual space enabling learners to freely explore ideas, concepts, and the shared knowledge available on the semantic web and the communities that they are part of. This innovation is co-designed, implemented and tested in systematic interaction and exchange with stakeholders following participatory design and participative evaluation principles. This happens in and around school communities covering a learner age spectrum from 10 to 18+ years.

### *About this document*

The purpose of the present document is to describe the design and implementation of the Creativity Profiling Server (CPS) component within C2Learn.

The document describes the architecture of CPS, summarizes the functionality of each integrated module and reports on the construction and maintenance of the users' creativity profile based on the creativity showcased by their creations.

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## 1. INTRODUCTION

### 1.1 USER PROFILING IN C2LEARN

Under the overall goal of fostering creativity via playful activities, C2Learn aims to incorporate technologies that monitor the creativity of the participating users, and build a Creativity-centric profile for each of them, based on their activities and the assessment creativity techniques employed during the learning process.

To this end, the initial architecture for a C2Learn profiling service, as reported in deliverable D3.41, aimed at providing a centralized repository for both the user's characteristics and their activities in the overall C2Learn environment, including the distinct C2Learn games and the C2Space platform.

*In order to improve the extensibility and reusability of the Creativity-centric profiling functionalities, and furthermore, to handle more efficiently data privacy and sensitivity issues, which importance was stressed during the 1<sup>st</sup> Project Review, several architectural changes were applied in the service.*

*More specifically, the new version of the Creativity Profiling Server (CPS) is focused on storing, maintaining and analysing those constructs that strictly pertain to a user's creativity. Furthermore, the data collected by the CPS is completely anonymized, no personal information is maintained, and the association with a specific user is known only to the calling application (C2Space), as analysed in Section 3.1 of this document.*

Personal information, such as age, gender, etc., is handled and stored within the de-centralised installations of C2Space (for details please refer to D4.4.x C2Learn Game Prototyping).

### 1.2 CREATIVITY PROFILING SERVER FUNDAMENTAL DESIGN PRINCIPLES

The design and implementation of the Creativity Profiling Service relies on specific concepts related to (a) the reasoning practices employed by the user and (b) the means of expressing the reasoning via artefacts of different forms.

As stated by the theoretical foundation of C2Learn, there are three core reasoning techniques related to creativity. Namely, we are concerned with the following reasoning techniques:

1. Semantic Reasoning
2. Diagrammatic Reasoning
3. Emotive Reasoning

Each of these reasoning types correspond to a creativity dimension, with specific characteristics and features. To this end, the conceptualization of the creativity profiles are based on the dimensions defined by the respective reasoning techniques.

The present deliverable describes the conceptualization of human creativity assumed by the Creativity Profiling Server and describes the server's design and implementation that serves the theoretical foundation for defining and updating a user's creativity profile. The current implementation covers the semantic dimension of creativity, as expressed via textual artefacts, while the overall architecture of the system is designed to incorporate the other dimensions of creativity, as will be defined in the next version of the service.

## 2. CREATIVITY PROFILING SERVICES CONCEPTS

The core assumption for building a user's creativity profile, is that his/her creativity is showcased by his/her creations, named Creativity Exhibits. These exhibits can follow different modalities, corresponding to the aforementioned reasoning patterns, e.g. texts, diagrams/pictures, actions etc.

The type of creativity exhibits that CPS can handle are divided into three categories:

1. Semantic Reasoning Exhibits (SRE): This category concerns textual exhibits, such as stories.
2. Diagrammatic Reasoning Exhibits (DRE): This category concerns diagrams and image creations as exhibits
3. Emotive Reasoning Exhibits (ERE): This category concerns the behavioural actions of a user and will be further analysed in the next version of CPS (Deliverable D3.4.3).

The calculation of a creativity profile, therefore, constitutes the process of (a) measuring the creativity expressed by given creativity exhibits; (b) associating these measurements with dimensions of human creativity corresponding to the given dimension.

For achieving (a), we employ creativity metrics derived from computational creativity and formulate them in accordance to the characteristics of the examined exhibits.

A number of different creativity metrics are proposed from the literature on computational creativity [1]. More specifically, Novelty reflects the deviation from existing knowledge/ experience and can be measured as a difference metric between what is already known and the given piece of content. Novelty is a generally accepted dimension of creativity within the area of computational creativity and an essential candidate for measuring elements of creativity within the human-created content when interacting with the machine. It has been used as a heuristic for driving the generation of novel artefacts in exploratory creativity [1] known as novelty search, an approach to open-ended evolution in artificial life [2].

Surprise is another essential characteristic which may be represented as the deviation from the expected. The higher the deviation the higher the perceived surprise. Surprise offers a temporal dimension to unexpectedness [3].

Likewise, impressive artefacts readily exhibit (ease of recognition) significant design effort and may be described via two heuristics, Rarity (rare combination of properties) and Recreational Effort (difficult to achieve) [4].

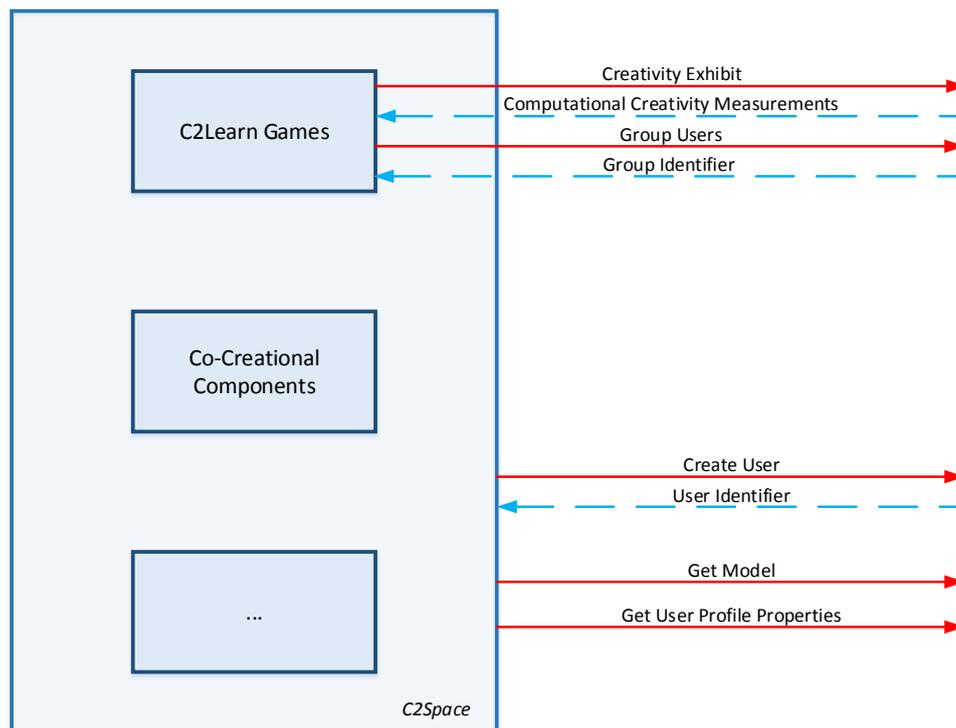
These four metrics will be used to construct the creativity profile of a human user, as expressed by the artefacts that this user has been constructed alone or as a participating member of a group of users. In the case of Semantic Reasoning Exhibits, examples of such artefacts include a written story, a dialogue and any other textual creation.

The following section describes the overall architecture of the Creativity Profiling Server, defining the way that the creativity exhibits are propagated and processed by the server in order to produce the Creativity Profiles of its registered users.

### 3. CPS ARCHITECTURE

#### 3.1 ARCHITECTURE

The Creativity Profiling Server (CPS) architecture and implementation allows the storage, maintenance and update of creativity profiles of users using creativity exhibits that are produced from applications of the outside world. CPS provides a simple and straightforward API in order to expose its functionalities and to facilitate the communication with the outside world. The following figure depicts an exemplary application inspired from C2Learn project. Through the CPS API, the example application can submit creativity exhibits and receive the corresponding creativity measurements, create group of users and finally receive the creativity profile of a user.



**Figure 1: Example of Client Application**

The aforementioned functionalities and the internal structure of CPS are depicted to the following figure.

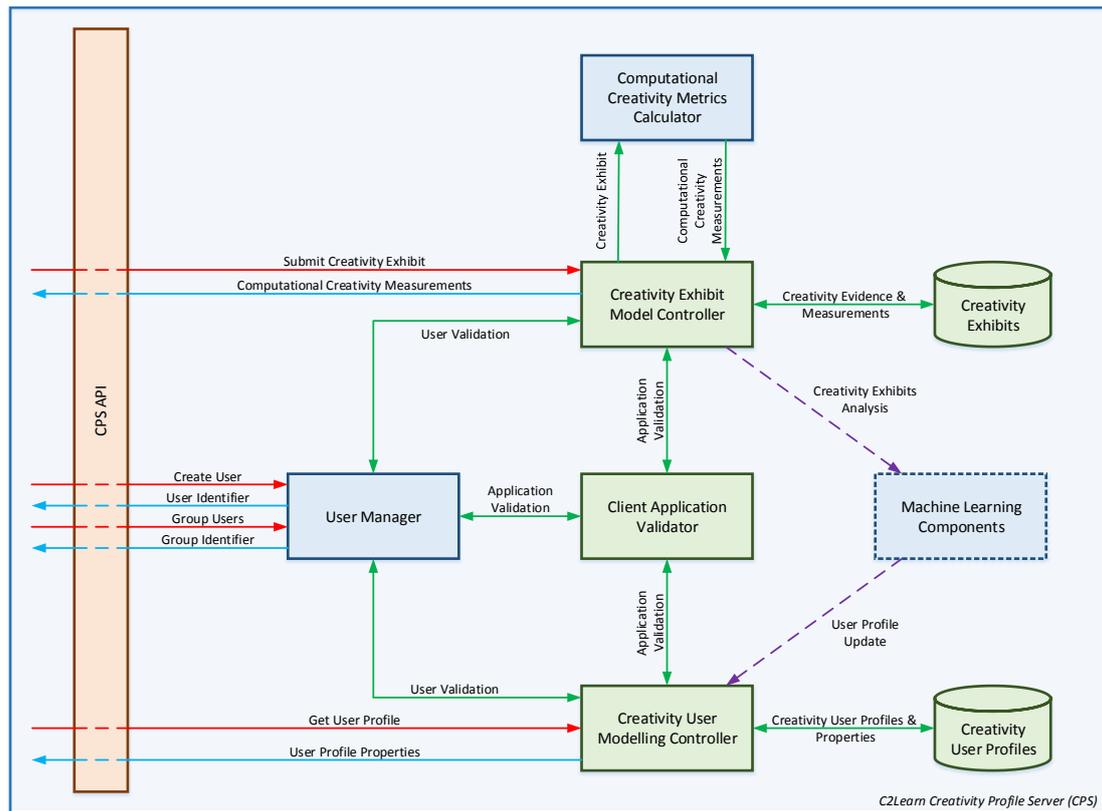


Figure 2: CPS Architecture

### 3.2 CPS COMPONENTS

The following table summarizes the distinct modules incorporated in the CPS architecture

| CPS Module Description       |   |   |                                    |
|------------------------------|---|---|------------------------------------|
| Name                         | Role  | Input                                   | Output                             |
| Client Application Validator | This module is responsible for ensuring that a client request is originated from an application registered to CPS   | Application Key                         | Valid/ Not Valid                   |
| User Manager                 | This module is responsible for ensuring that client requests contain a valid user profile ID. Also User Manager is responsible for creating and destroying groups by joining and disjoining user profile properties respectively. | User Profile ID<br>User Profile ID List | Valid/ Not Valid<br>Group ID       |
| Creativity Exhibit Model     | This module is responsible for storing, maintaining and updating the creativity exhibits delivered by applications and  | Creativity Exhibit                      | Creativity Exhibit & Computational |

|   |   |  |                                       |
|---|---|--|---------------------------------------|
| Controller                                  | also forward the creativity exhibits to the Computational Creativity Metrics Calculator.  |  | Creativity Measurements               |
| Computational Creativity Metrics Calculator | This module is responsible for calculating all the metrics of an creativity exhibit regarding of its type   | Creativity Exhibit                     | Computational Creativity Measurements |
| Creativity User Modelling Controller        | This module is responsible for storing, maintaining and updating the Profile Properties of each User Profile in CPS. Also this module delivers to client applications the properties of particular user profiles. | User Profile ID<br>Creativity Exhibits | User Profile Properties               |
| Machine Learning Components                 | This module is responsible for calculating the value of the Creativity Profile Properties of a given user   | User Profile ID<br>Creativity Exhibits | User Creativity Profiles Properties   |

**Table 1: CPS Components**

### 3.3 CPS WORKFLOW

In a typical situation an application creates a user through the CPS API. The CPS API send the request to the User Management. Afterward User Management verifies through the Application Validation module that the application is registered to CPS. Since the application is validated User Management creates a unique user profile id and sends it to the application.

Since a user profile is created then the application can submit creativity exhibits of this user. More specifically the application submits the creativity exhibit to the CPS API along with type of the creativity exhibit and the timestamp the creativity exhibit was created.

After submission the API sends the creativity exhibit and its type to the Creativity Exhibit Model Controller module. After validating the user and the application through the User Management and the Application Validator respectively, the module sends the creativity exhibit to the Computational Creativity Metrics Calculator module.

The Computational Creativity Metrics Calculator returns back he measurements of the creativity exhibit.

Afterwards, the Creativity Exhibit Model Controller module stores the creativity exhibit along with the measurements to the CPS database.

Finally, the Creativity Exhibit Model Controller invokes the Machine Learning Components. Machine Learning Components take as input the creativity exhibit and calculate the values of the profile

properties of the user. Afterwards the newly calculated values are sent to the Creativity User Modelling Controller module, which stores the values to the CPS database.

Once a user creativity profile is created, then the application can request through the CPS API the User Profile Properties and also the Model which describes the profile. After sending the request to the API, the request is redirected to the Creativity User Modelling Controller module. This module, after validating the user and the application through the User Management and the Application Validator respectively, retrieves from the CPS database the properties for the corresponding user and send them back to the application.

Another functionality that an application can exploit through the CPS API, is the creation of groups. In this case the application send the user profile id that are to be grouped and the API send the request to the User Manager module. After validating the users and the application through the User Management and the Application Validator respectively, the module creates the group profile along with a unique id and returns it to the application.

#### 4. CALCULATION OF COMPUTATIONAL CREATIVITY METRICS

This section describes the formulization of the aforementioned four Computational Creativity metrics for Semantic Reasoning Exhibits, as implemented in the Computational Creativity Metrics Calculator component of the CPS.

##### 4.1.1 NOVELTY COMPUTATION

In the context of textual information, novelty can be defined as the average semantic distance between the dominant terms included in the text, compared to the average semantic distance of the dominant terms in all texts. For the implementation of the Novelty Computation tool, we use the thirty most frequent terms in each segment (after the removal of stopwords and the stemming of the remaining terms) as the set of dominant terms. More formally, let  $S_G$  be the set of examined texts created by the group  $G$ ,  $T$  the set of dominant terms in the text belonging to  $G$  and  $T_n$  the set of dominant terms in a text segment  $S_n$ . The average semantic distance for  $S_n$  is defined as:

$$D(S_n) = \frac{\sum_{i,j=1}^{|T_n|} sem(T_{ni}, T_{nj}), i \neq j}{|T_n|}$$

Similarly, the average semantic distance for the complete set of text segments is defined as:

$$D(S_G) = \frac{\sum_{i,j=1}^{|T_G|} sem(T_i, T_j), i \neq j}{|T_G|}$$

Given this, the Novelty of a text segment  $S_n$  is equal to the absolute difference between its average semantic distance and the overall semantic distance, normalized to the [0,2] value space.

$$Nov(S_n) = 2|D(S_n) - D(S_G)|$$

##### 4.1.2 SURPRISE COMPUTATION

As stated, surprise has a strong temporal dimension, as the surprise element largely depends on the departure from an already established context. To this end, the *Surprise Computation* service operates on a fragment set produced by a text segment. We conceptualize surprise as the average semantic distances between the consecutive fragments within this fragment set, normalized in the [0, 2] space.

$$Sur(S_n) = \frac{2}{|F| - 1} \sum_{i=2}^{|F|} |D(F_i) - D(F_{i-1})|$$

where  $F$  is the set of fragments  $F_i, i \in \{1, \dots, |F|\}$  of the complete text segment  $S_n$ .

#### 4.1.3 IMPRESSIVENESS COMPUTATION

As stated, Impressiveness is in general dependent on two distinct characteristics of an artefact; its rarity, i.e. how infrequent is the artefact with respect to specific characteristics that it exhibits; and its recreation effort, i.e. how difficult it is to reproduce the artefact. We handle these two characteristics independently, as two aspects of impressiveness modelled as follows:

**Rarity:** We use the clustering methods implemented in the Text Clustering tool in order to compute the clusters of terms in the input text. Following the same approach applied to the computation of the novelty metric, we calculate the semantic distance between the individual clusters. In order to provide an estimation of the rarity for a given text, we calculate the sum of weights on the min-weight closure of the cluster graph compared to the maximum sum of weights in the text set of the group and normalized it in the  $[0, 2]$  space.

$$Rar(S_n) = 2 \frac{MinClosureW(S_n)}{\max(MinClosureW(S_i))}, i \in \{1, \dots, |S_G|\}$$

where  $MinClosureW(S)$  is the sum of weights in the min-weight closure of the term graph representing artefact  $S$ .

**Recreation effort:** Recreation effort is calculated as the number of different clusters that each text contains, compared to the maximum number of clusters found in a text segment and normalized in the  $[0, 2]$  space.

$$Eff(S_n) = 2 \frac{|Clusters_n|}{\max(|Clusters_i|)}, i \in \{1, \dots, |S_G|\}$$

## 5. COMPUTATION OF HUMAN CREATIVITY DIMENSIONS

As stated, each textual artefact can be described by 4 computational creativity metrics, namely, Novelty, Surprise, Rarity and Recreational Effort. However this system of four variables is not orthogonal, thus, Surprise, Rarity and Recreational Effort should be combined to form another metric, which we call Atypicality and is orthogonal to Novelty. Atypicality is calculated as a weighted average of Surprise, Rarity and Recreational Effort, as follows:

$$AT_i = \frac{w_S * S_i + w_R * R_i + w_E * E_i}{w_S + w_R + w_E} \quad [Eq.1]$$

Where:

$i$  refers to an artifact,  $S_i$ ,  $R_i$ ,  $E_i$  and  $AT_i$  to Surprise, Rarity, Recreational Effort and Atypicality metrics respectively for the given artifact  $i$ , and  $w_S, w_R$  and  $w_E$  are positive weights assigned to Surprise, Rarity and Effort respectively, in order to calculate the Atypicality metric in a way as much uncorrelated (and thus, orthogonal) with Novelty as possible.

A user's Creativity Profile consists of a two-dimensional vector expressing two types of user's creativity. The Visionary Creativity, which is measured by the Novelty metric, and the Constructive Creativity, which is measured by the Atypicality metric.

CPS gathers all Creativity Exhibits (artefacts) that are produced by its users within external applications. In discrete time intervals, which we call Time Window, CPS calculates and/or updates the Creativity Profile of each user.

The calculation of the creativity profiles for the users of the CPS is a repeated (once per Time Window) two-phase process, and is explained below:

Phase A: Calculation of optimum Computational Creativity Metric Weights for the Application Domain

We aim to find/ update the weight values  $[w_S, w_R, w_E]$  of Surprise, Rarity and Recreational Effort that constitute Atypicality orthogonal to Novelty, i.e. those weight values for which  $\text{Correl}(N, AT) = 0$ .

The optimum vector  $[w_S, w_R, w_E]$  will be used in Phase B for the calculation of the users' Creativity Profiles for the new CPS Time Window.

We thus define the following non-linear optimization problem:

$$\text{Min. } \text{Correl}(N, AT)^2 \quad [\text{Eq.2}]$$

st.

$$w_S, w_R, w_E \geq 0$$

$$w_S + w_R + w_E \neq 0$$

Each time where a new CPS Time Window starts, we solve the above minimization problem for all the artefacts of the application domain (all the creativity exhibits collected for all CPS users and for all CPS Time Windows so far).

It is evident that in each execution of this process there is a strong probability of discovering a new vector  $[w_S, w_R, w_E]$  that makes Atypicality (AT) more orthogonal to Novelty (N). In order to reduce the sensitivity of the system to this continuous change, we update the vector  $[w_S, w_R, w_E]$  to be used in Phase B with the new vector retrieved by solving the optimization problem defined in Eq.2 only when the improvement (minimization) in  $\text{Correl}(N, AT)^2$  exceeds 5%.

Phase B: Construct/update of Users' Creativity Profiles

A user's creativity profile is determined by the creativity exhibits produced by the user alone or as a member of a group.

Groups are treated by CPS as a user, meaning that CPS will construct a creativity profile also for each group. In this case, the creativity profile is constructed/ updated based on the creativity exhibits of the group during the last (just finished) time window.

In the case of simple users (not groups) their creativity profile is constructed/ updated based on all the creativity exhibits they constructed (either alone or as a group member).

The first step for computing the creativity profiles is to transform the space  $(N, S, E, R)$  to the space  $(N, AT)$  and compute the average of N and AT measures for the creativity exhibits for a given user and for the time window that just finished, as follows:

### B1. Calculate Average Novelty and Atypicality of Creativity Exhibits

In the general case, let a user U which participates in groups UG.

In the case of computing the creativity profile of a group, we have only the user U, which represents the group. Such a user cannot be part of other groups.

Let  $E_T \equiv [\overline{Novelty}, \overline{Atypicality}]$  of a user U, calculated for the creativity exhibits in the time window T, after the transformation of the space (N,S,E,R) to the space (N, AT) using the optimal weight vector [wS,wR,wE] (calculated in Phase A).

Let also  $G_T \equiv [\overline{Novelty}, \overline{Atypicality}]$  of a user U, calculated for the creativity exhibits of UG in the time window T, after the transformation of the space (N,S,E,R) to the space (N, AT) using the optimal weight vector [wS,wR,wE] (calculated in Phase A).

The overall Average Novelty and Atypicality (PT) of all creativity exhibits for user U is calculated as a fusion of ET and GT, relying on the analogy of the user's and the groups' achievements.

If the user's creativity (ET) surpasses the creativity exhibited within his/her participation in groups (GT), then only ET is considered. Otherwise, a part of the difference between groups' creativity and user's creativity is also considered, as follows:

$$P_T = \begin{cases} E_T & E_T \geq G_T \\ E_T + k * (G_T - E_T) & E_T < G_T \end{cases} \quad [\text{Eq.3}]$$

where:

$$k = \frac{1}{2} + \frac{1}{2} * \tanh(2 * [(G_T - E_T) - 1]) \quad [\text{Eq.4}]$$

### B2. Calculate Visionary and Constructive Creativity of User

Though all exhibits must be taken into account, the recent ones are considered more important, as they depict the exact current status of the user's creativity whereas past exhibits play a less vital role. To give our model an essence of decay through time, we use this formula:

$$C_T = \frac{P_T}{D} + \frac{D-1}{D} * C_{T-1} \quad [\text{Eq.5}]$$

Where:

$C_T$  is the vector describing the Creativity of the user (or group) at the time window T, and  $C_{T-1}$  at the time window T-1 respectively

$$C_T \equiv [\textit{Visionary Creativity}, \textit{Constructive Creativity}]$$

and D, a proportional constant of decaying analogous to the timespan.

## 6. CPS API FUNCTIONALITIES

The CPS API provides a set REST services. These services allow the communication with CPS and use its profiling capabilities.

### 6.1 CREATE USER PROFILE

This service creates a user profile in the context of CPS. More specifically, it creates a user profile with a unique id and assigns the user to the given application.

| Parameters             |                                    |
|------------------------|------------------------------------|
| <b>Application key</b> | The identifier of the application. |

### 6.2 SUBMIT CREATIVITY EXHIBIT

This service allows to an application to submit in CPS a creativity exhibit for a specific user. In the request should be also included not only the creativity exhibit but also, the type of the creativity exhibit, the user profile id, the application key and the timestamp of the creativity exhibit. This service returns to the application the measurements for this creativity exhibit.

| Parameters                     |  |
|--------------------------------|--|
| <b>Application key</b>         | The identifier of the application.               |
| <b>User Profile ID</b>         | The identifier of the User Profile               |
| <b>Creativity Exhibit</b>      | The creativity exhibit                           |
| <b>Creativity Exhibit Type</b> | The type of the creativity exhibit               |
| <b>Timestamp</b>               | The timestamp the creativity exhibit was created |

### 6.3 GET USER CREATIVITY PROFILE

This service allow an application to request and receive the creativity profile of a user.

| Parameters             |                                    |
|------------------------|------------------------------------|
| <b>Application key</b> | The identifier of the application. |
| <b>User Profile ID</b> | The identifier of the User Profile |

### 6.4 GET MODEL

This service allows the review of the User Creativity Profile Model.

| Parameters             |                                   |
|------------------------|-----------------------------------|
| <b>Application key</b> | The identifier of the application |

## 6.5 CREATE A GROUP

This service allows the creation of a Group which encapsulates the given user profile id's.

| Parameters                  |   |
|-----------------------------|---|
| <b>Application key</b>      | The identifier of the application                                   |
| <b>User Profile ID List</b> | A list with the user profile ids that will be included to the group |

## 6.6 DESTROY A GROUP

This service allows the removal of a Group.

| Parameters             |                                     |
|------------------------|-------------------------------------|
| <b>Application key</b> | The identifier of the application   |
| <b>Group ID</b>        | The id of the group to be destroyed |



## 8. CONCLUSIONS & NEXT STEPS

The present report provides a summary of the architectural design and functionality of the C2Learn Creativity Profiling Server (CPS). The CPS aims to anonymously handle and store all the creativity exhibits created by a given user and construct the latter's creativity profile in three distinct reasoning dimensions, as defined by the underlying C2Learn theory.

The CPS is designed to support exhibits for all three different reasoning dimensions foreseen in C2Learn. At its current implementation, the CPS handles artefacts pertaining to the Semantic Reasoning dimension. The next version of the CPS will incorporate the required extensions for handling Diagrammatic and Emotive Reasoning exhibits.

An important next step is the usage of the Creativity Profiling Server towards associating each user with a creativity category as defined in the context of WP2. To this end, and by using the categorization for each user as derived from the piloting sessions within the project, the Creativity Profiling Server will incorporate Machine Learning techniques in order to cluster users in the appropriate categories, with respect to their Creativity Profiles as maintained in the CPS.

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