

# Project team formation support for self-directed learners in social learning networks

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# PROJECT TEAM FORMATION SUPPORT FOR SELF-DIRECTED LEARNERS IN SOCIAL LEARNING NETWORKS

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## ABSTRACT

Despite their name, social learning networks often lack explicit support for collaborative learning, even though collaborative learning offers benefits over individual learning. The outcomes of collaborative, project-based learning can be optimized when team formation experts assemble the project teams. This paper addresses the question of how to provide team formation services to individual, self-directed learners in a social learning network so they can make use of and profit from project-based learning opportunities. A model of a team formation process is presented, based on current team formation theory. It is used to design an automated team formation service that can be used by self-directed learners to form teams for project-based learning. Starting from a project description situated in a knowledge domain, the model defines three categories of variables that govern the team formation process: (I) *knowledge*, (II) *personality* and (III) *preferences*. Learner data on these categories are combined in a measure of fit, which calculates the best team for a project. A novelty introduced is that, depending on the desired project outcomes the relative weight of the categories can be altered to optimise the project formation process. The feasibility of the approach is demonstrated in an example in which the proposed algorithm is used to determine the most productive team for a project. Finally, future work and research are indicated.

## KEYWORDS

Social learning networks, project-based learning, project team formation, self-organisation, self-directed learning, team formation service

## 1. INTRODUCTION

Catering for our desire to learn, the Internet has given us the ability to connect to people all over the world. Nevertheless, when we visit a site with interesting learning materials and possible co-learners and we want to start a collaborative learning project, we will find little support. How can we become part of a team when we want to start a learning project when we know next to nothing of our co-learners and their learning interests?

Supporting learners in such distributed settings, like Learning Networks (Koper and Sloep, 2002; Sloep and Berlanga, 2011), differs from supporting learners in initial formal education (Sloep, 2009), because of the learner's self-directed and unsupervised learning behaviour (Ellinger, 2004). In distributed settings, project-based learning and team formation support services are not readily available. To address this need, we present a design for a service that can support distributed learners in forming teams. Prior research indicates that for project-based learning to deliver optimal results, experts should form the teams (Oakley et

al., 2004; Fiechtner and Davis, 1992; Fiechtner and Davis, 1985; Obaya, 1999). As these experts are not readily available in social learning networks, our design aims to mimic expert behaviour, but also to take into account learner self-direction and self-organisation. The concept of *fit* (both complementary and supplementary) (Werbel and Johnson, 2001; Kristof, 1996) is used to indicate whether a team of learners (in its unique combination of knowledge, personality and preferences) is fit to perform a specific project. We propose, by varying the levels of fit in learner *knowledge* and *personality*, a novel team formation approach that allows for specifying targets in the project outcomes. These targets can be, for example, facilitating learning from other team members while solving the project problem, coming up with creative solutions, or expertly and productively solving the project problem.

We introduce our analysis of project-based learning and team formation (Section 2), and relate it to the practice and the opinion of experts from the educational field. We then move on to define a team formation model (Section 3) and design a team formation service (Section 4). We demonstrate how the service works on a test data set (Section 5) and finally draw conclusions and indicate future research (Section 6).

## 2. PROJECT-BASED LEARNING AND TEAM FORMATION

Compared to individual learning, collaborative learning leads to an improvement of learning outcomes (Hsiung, 2010). There are a number of reasons for this improvement (Springer, Stanne and Donovan, 1999; Felder, Felder and Dietz, 1999): the more intense engagement with the subject matter, the increased socialization and exposure to different ideas, and the intensified level of information processing. Naturally, collaborative learning can only occur when learners operate in teams, whether long lasting or formed ad hoc (Sloep, 2009), where a team is defined as “a group of people working together on a well-defined task or set of tasks” (Ounnas, Davis and Millard, 2007).

To form effective teams, a team formation expert requires data on the prospective team members and the project. Prior research defines these variables:

a) The individual learner’s knowledge from prior learning achievements, b) The individual learner’s personality traits, personal skills, gender, personal interests and motivational orientation, c) The curriculum area in which the project task will be positioned and d) The project task itself and, as a derivative, the team size related to the duration of the project and the work that has to be done. (Graf and Bekele, 2006; Martín and Paredes, 2004; Slavin, 1989; Wilkinson and Fung, 2002).

Given the social network learning settings we aim to support, we face the question how data on these variables can be acquired, and how they should be weighed against each other. Prior research already resulted in a number of team formation support applications. These Computer Supported Group Formation (CSGF) applications use team formation variables such as domain knowledge, learning goals, performance in previous teamwork, specific expertise, preferred time slots and preferred projects, performance and personality traits (see Ounnas, Davis and Millard (2009) for an overview). However, they offer limited solutions or work in specific conditions only. Often they are only usable in traditional (classroom) learning settings or must rely on data available in for instance a learning management system. Furthermore, they are aimed at specific learning situations, i.e. they offer limited opportunities to specify the targets for the project-based activities outcomes, as we suggested would be desirable in Section 1. Our research aims to overcome these deficiencies and presents a new and flexible, more general approach to the team formation process.

## 3. APPROACH AND MODEL OF THE TEAM FORMATION PROCESS

We propose that most of the team formation process variables (as mentioned in Section 2), fit into two categories: I) *Knowledge* (about the learner’ knowledge, the curriculum and the project task, etc. as mentioned in points a, c and d), and II) *Personality* (the learner’ personality, interest and motivation, etc. as mentioned in point b). However, for internationally dispersed self-directed learners, obviously a third category of variables is relevant: III) *Preferences* (including variables such as possible collaboration language(s), an availability schedule, time zone and preferred collaboration tools (cf. Fetter et al, submitted).

In order to test these initial ideas, we conducted a limited inquiry into team formation practice. We designed a questionnaire, which was presented to a broad range of respondents from the educational field,

which included international groups working with project-based learning settings. The 26 respondents stemmed from 8 different European countries. Of the respondents 29% were female, while 71% were male; 73% worked at a university, 15% worked at a university for Professional Education, while 4% worked in vocational training. Two respondents did not fully answer all questions in the questionnaire.

The answers revealed that, in order to create teams, a significant part of the respondents used simple, pragmatic heuristics, unrelated to any team formation theory: for example, respondents randomly selected team members (37%) or allowed students to self-select teams (50%).

The respondents rated the importance of the contribution of the categories *knowledge*, *personality* and *preferences* to the team formation process (see Table 1). When we combine the top-two scores of the individual categories, *knowledge* is rated as rather important to very important by 64%, *personality* by 12% and *preferences* by 60% of the respondents respectively. This indicates that the respondents do not put the same emphasis on the category *personality* as an important contributor to successful team formation as is the case in the team formation theory we examined in section 2.

Table 1. The importance of the categories knowledge, personality and preferences in the team formation process, on level of importance

Importance	Knowledge	Personality	Preferences
Very important	28%	0%	16%
Rather important	36%	12%	44%
Important	28%	24%	28%
Somewhat important	8%	44%	12%
Not important	0%	20%	0%

The respondents showed less clear views on the possibility to influence the targets of the project-based activities. Not surprisingly, however, considering the respondents educational backgrounds, the target “improved learning” scored highest, with the top two importance scores accumulating to 76%, while “enhanced creativity” scored 64% and “improved productivity” scored 48%. This suggests a succession of preferred outcomes from “improved learning” to “enhanced creativity” to the least favoured “improved productivity”.

Table 2. Preferred target outcomes of project-based activities, on level of importance

Level of importance	Improved learning	Enhanced creativity	Improved productivity
Very important	48%	20%	8%
Rather important	28%	44%	40%
Important	24%	16%	36%
Somewhat important	0%	20%	12%
Not important	0%	0%	4%

Based on these findings we proceeded to create a model for the team formation process that uses the three categories and places the project team formation process in a project-based learning setting.

### 3.1 A Model for the Team Formation Process

Based on the findings just reported, in our view, team formation for project-based learning should start with the definition of a project related to a part of a knowledge domain (such as a curriculum or subject of interest). Next, the fit of the prospective team members should be determined with respect to their *knowledge*, *personality* and *preferences*, related to the project and other members. The team formation process then ends with a suggestion for a project team when *one* set of project-suitable members can be found that shows optimum fit (the best fit team solution), or when *all* members are dispersed over teams (the best possible average solution). Figure 1 depicts the model showing this process. This team formation for project based learning model might readily be recognized in traditional educational settings, where the expert (e.g., the teacher) would normally initiate projects. However, when we compare the self-organised social learning contexts that we aim to support to the traditional (classroom) learning settings, the expert role is

most probably not available. Therefore the question arises how project-based learning and a team formation process could be initiated in the educational settings we are interested in for this paper.

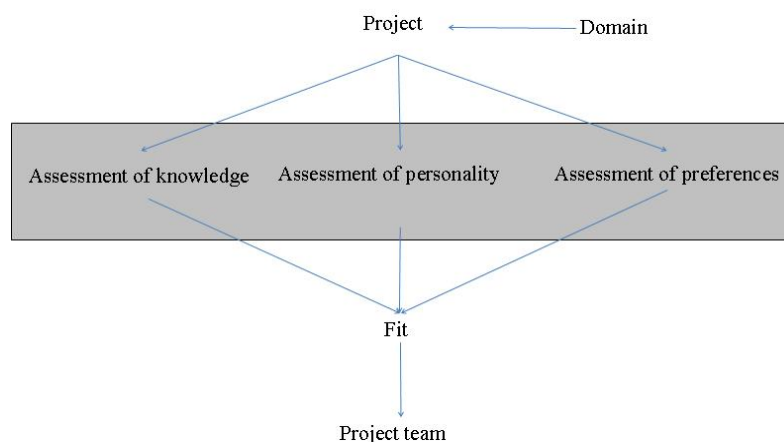


Figure 1. The proposed model for the team formation process; projects are defined inside a domain; prospective team members' knowledge, personality and preferences are analysed, which leads to a measure of fit, based on which team formations are proposed

#### 4. GENERIC TEAM FORMATION SERVICE DESIGN

The dispersed learning contexts for which we design a team formation service requires us to consider the effects of learner self-direction, self-organisation, self-service and the learning settings themselves, in particular in contrast with traditional learning settings. In the social learning network context: a) a team formation service can be based on the learning materials in the domain and the project description in relation to a learner's *knowledge*, complemented with a learner's *personality* and *preferences*, b) a project is started by a learner (or a stakeholder connected to the network) who provides a project description, and c) the project is not necessarily positioned in a well-defined curriculum, therefore prospective team members can have a wide variety of knowledge backgrounds and project-related preferences.

We address these effects by following the categorization of the team formation related variables introduced earlier. We design the assessment of the fit between the required and available knowledge to be handled by a *knowledge proxy*, and the assessment of fit between learner personalities to be handled by a *personality proxy*. The learner's project work related preferences are assembled in a *preferences profile*.

The knowledge proxy operates on available textual materials: a) the learning materials in the domain, b) a project description (from which subject knowledge requirements are inferred) and c) the knowledge evidence provided by the learners (for example, a project application detailing relevant knowledge on the subjects the project is concerned with). Building on prior research by Laham, Bennett and Landauer (2000), which demonstrated the successful matching of people to jobs and learning materials, using Latent Semantic Analysis (LSA) (Landauer, Foltz and Laham, 1998; Landauer, 2007), we suggest to use such language analysis technology to perform the knowledge analysis. This will, however, first be implemented in the final version of the team formation service. Since here we only aim to demonstrate the feasibility of a team formation service, we will analyse a small set of artificial test data.

The personality proxy is currently envisaged to evaluate the personality profile factor *conscientiousness*, which predominantly predicts a person's future performance in a team. Conscientiousness generalises a person's *carefulness*, *thoroughness*, *sense of responsibility*, *level of organization*, *preparedness*, *inclination to work hard*, *orientation on achievement* and *perseverance* (Goldberg, 1990; Schmidt and Hunter, 2004; Jackson et al., 2010). The conscientiousness score will be established by using the Big Five personality test (Barrick and Mount, 1991). However, we are considering to include other personality factors and personal skills for the personality proxy to evaluate. This could broaden the profile and mitigate risks of retest effects.

For instance, we could also take into account personality aspects, such as *extrovertness*, and personal skills, such as computer programming ability, depending on a classification of the project description.

The learner's *preferences* are established using a preferences profile, which includes data on variables such as *availability*, *time zone*, *preferred collaboration language* and *tools*. The fit between learners with respect to project work related preferences are treated as *condicio sine qua non*. (E.g., one learner indicates to be available only on Mondays, while another learner indicates to never be available on Mondays, so their calendars are mutually exclusive and thus these two learners will never be matched in a team).

It is important to notice that the data gathered on learners is *not of a static nature*, but can be refreshed every time a learner re-enters knowledge evidence for a project in which the learner wishes to participate or retakes the personality test or updates preferences.

The team formation service combines the data and suggests possible team(s), by matching learners who, in a specific combination, have knowledge of the required subjects and who, in a specific combination, have matching conscientiousness levels and have overlapping preferences.

The envisaged team formation service offers the unique ability to influence (or predict) the outcomes of the project-based activities by allowing changes to the combination in which prospective team members have to show fit in the *knowledge* and *personality* categories. In the design of this influencing ability, we took into account the following research findings:

- a) Learning is fostered when team members provide a complementary fit in knowledge backgrounds and show a supplementary fit in personalities (Werbel and Johnson, 2001).
- b) Too much complementary fit in knowledge can lead to a loss of creativity and group thinking (West, 2002).
- c) People with higher conscientiousness scores tend to be less intelligent when compared to people with lower conscientiousness scores (in academic settings). They make up for intelligence deficits by exhibiting the behaviour related to high conscientiousness scores (Moutafi, Furnham and Paltiel, 2004).
- d) People with high conscientiousness scores tend to be less creative (George and Zhou, 2001; Wolfradt and Pretz, 2001).
- e) Forming teams from learners who have different conscientiousness scores impedes their task negotiations after the project team has been formed, which would then hinder the team task execution (Gevers and Peeters, 2009).
- f) Groups with members that possess different knowledge backgrounds will be more innovative because they contribute different perspectives (Paulus, 2000).
- g) Successful research teams are comprised of heterogeneous members (Dunbar, 1997).
- h) Members of productive teams should be capable and conscientious and must have domain knowledge (Isaksen and Lauer, 2002).
- i) There is a maximum distance in knowledge that can be bridged in collaboration with more capable peers (zone of proximal development, Vigotsky, 1978).
- j) Mutual teaching and learning are among the most important activities in defining and solving problems (Paulus, 2000).

Inferring from these findings, we defined the influence these findings can have when they are used for matching learners into teams aiming at specific outcomes, i.e.: (1) facilitating learning, (2) productive problem solving, or (3) creative solutions. Table 3 provides an overview of their effects on project outcomes and the requirements for matching learner knowledge and conscientiousness scores.

Table 3. Influence hints towards targeted project-based activities outcomes

Influence hint from:	Target outcomes	Knowledge	Conscientiousness
Moufati et al.; Gevers and Peeters; Isaksen and Lauer	Productive problem solving	More supplementary	All higher
George and Zhou; Wolfradt and Pretz; West; Paulus; Dunbar	Creative solutions	More complementary	All lower
Werbel and Johnson; Vigotsky, Paulus	Facilitating learning	More complementary	All higher

In order to test the generic team formation design we fed a team formation algorithm with a small set of test data. In the next section we present the team formation results from the algorithm for the formation of productive teams.

## 5. RESULTS

Based on the target outcomes (Table 3), we defined the algorithms that set the stage for the formation of creative, productive or learning teams. Bringing back to mind the team formation service design, we should note that the test data set presented in Table 4 presupposes that the project description analysed referred to knowledge on 4 topics. It further presupposes that learners handed in knowledge evidence on these 4 topics, which is reflected in the numerical scores in Table 4 (ranging from 1 to 10, where 10 is indicating the highest possible score on the topic). The conscientiousness scores in Table 4 are the results of the Big Five personality test (they range from 1 to 5, with 5 indicating the highest level). For simplicity, we assume that the learners show overlapping project activity preferences. Finally and somewhat arbitrarily, the desired team size was set be 4 learners per team.

Below we present the algorithm for the formation of productive teams. It searches for teams whose members have the highest average knowledge and the highest average conscientiousness (following the team formation suggestions for target outcome “Improve productivity” in Table 3). The measure of fit (a calculated value between “0” and “1”, with “1” indicating the highest possible fit) is calculated for every possible team ( $Fit_i$ ) of a chosen size from a set of learners. The fit is expressed by the following algorithm, in which  $Max\_Knowledge$  is 10,  $Max\_Consc$  is 5 and  $w_K$  and  $w_C$  are the weights of the categories knowledge and conscientiousness respectively (in the example both weights are 1).

$$Fit_i = 1 - \frac{w_K * (Max\_Knowledge - Avg\_Knowledge_i) + w_C * 2 * (Max\_Consc - Avg\_Consc_i)}{(w_K + w_C) * ((Max\_Knowledge + (2 * Max\_Consc)) / 2)}$$

Figure 2: Team formation algorithm for productive teams.

When this algorithm is applied to the test data set given in table 4, all possible combinations (i.e.  $(20 * 19 * 18 * 17) / (4 * 3 * 2 * 1) = 4845$  combinations) of 4 students are calculated for their fit value.

Table 4. Example student scores data set.

Student	Topic 1	Topic 2	Topic 3	Topic 4	Conscientiousness
Student 1	7	8	6	8	3
Student 2	8	9	8	7	4
Student 3	6	7	6	7	2
Student 4	6	9	7	8	4
Student 5	6	6	7	5	2
Student 6	7	7	8	6	4
Student 7	6	7	8	9	2
Student 8	8	8	7	9	4
Student 9	8	7	7	8	1
Student 10	5	6	6	7	4

A team “a” (comprised of students 1, 2, 6 and 8) has a fit value of 0.755, while a team “b” (with students 3, 5, 7 and 10) receives a fit value of 0.62. This then indicates that team “a” would be a more suitable candidate for the project.

## 6. CONCLUSION

We presented a model to provide self-directed, self-organising learners in social learning networks with support for collaborative project-based learning. We identified several learner- and task-related variables in

the team formation process and have shown how they fit into three categories: *knowledge, personality* and *preferences*.

Prior research indicated the importance of the factors knowledge and personality in the team formation process. Interestingly, this emphasis on personality was less articulated in our inquiry into current team formation practice. This may be due to the difficulty to establish a learner's personality. Nevertheless, we decided to include the personality factor in the suggested team formation approach in view of the large number of research studies that confirm its relevance. In any case, the importance of knowledge above personality can be varied in the algorithm by adapting the weights  $w_k$  and  $w_c$ .

In the subsequent construction of a model of a team formation process for project-based learning, the use of the principles of complementary and supplementary fit was proposed. Based on these findings, a self-service team formation service was defined. We gave an overview of research findings with regard to *knowledge and personality* and how they can be used to influence the project outcomes towards creative solutions, productive results or towards the facilitation of the learning process. We conclude that this novel possibility to influence project outcomes by varying the degree of fit between learners on *knowledge* and *personality* can be considered as an important feature of a team formation service. Finally, we have shown the feasibility of our approach by demonstrating an algorithm for the formation of productive teams.

Our future research will address the validation of the team formation algorithms and an extended definition and implementation of the learner profile. In a next step, we will examine the implementation and validation of the language analysis-based service for assessing projects and learners for required and available knowledge. Finally we aim to implement the team formation service in a social learning network for self-organised learners and validate it through experiment.

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