Team Formation for Research Innovation: The BRAIN Approach

Styliani Kleanthous Loizou[1], Vania Dimitrova[1], Dimoklis Despotakis[1], Jim Hensman[2], and Ajdin Brandic[2]

[1]School of Computing University of Leeds, UK
Styliani.kleanthous@googlemail.com
{scdd, v.g.dimitrova}@leeds.ac.uk
[2]Coventry University, UK
{ccx003, aa6345}@coventry.ac.uk

Abstract. Recently trends show that innovative research requires multidisciplinary teams. This brings forth the importance of team formation for innovation. In order to successfully identify who has to be in a specific team and what constitutes potentially successful multidisciplinary team collaboration, social processes important for team formation for innovation have to be understood. Based on this, technological approaches that can support these processes can be defined. This paper outlines key processes regarding team formation for innovation, following psychology and social sciences literature. We then present the BRAIN approach on forming multidisciplinary teams for innovation, which addresses some of the aspects identified in the literature. The paper revisits the current state of the BRAIN application, and recommends future work where user modelling, adaptation and personalisation approaches can be used to address the limitations identified

Keywords: Team formation, Expertise browsing, Intelligent support

1 Introduction

Recent trends in science and engineering require collaborative research by multidisciplinary teams. Funding organisations have acknowledged that innovation coming from addressing complex problems requires teams from multiple disciplines working together and approaching a problem from different perspectives. Thus, universities and research institutes set as strategic objectives to foster the development of multi- and cross- disciplinary collaboration teams. Institutional repositories which store researcher publications, projects, interests, form a valuable source for fostering multi-disciplinary team formation. However, such repositories are mainly used in a 'traditional' way as separate databases that provide information on demand. We consider here support to help establishing multi-disciplinary teams within an institution which function in virtual settings.

Multidisciplinary teams of people who collaborate with the purpose to create innovation have been defined by Peter Gloor [1] as "*a cyberteam of self-motivated people with a collective vision, enabled by the Web to collaborate in achieving a* *common goal by sharing ideas, information, and work*". There is an agreement in the literature that people in innovation teams have diverse knowledge and work towards a common goal. However, very little is done to support the formation of multi-disciplinary entities, which includes identifying who to be in a specific team and what constitutes a potentially successful multidisciplinary team. Hence, social processes important for team formation for innovation have to be identified.

A broad literature exists on processes and theories for supporting team formation in general. However, there is little work focusing on what processes are important when supporting team formation with respect to innovation. In this paper, we are reviewing the relevant literature of psychology and social sciences to identify what are the important processes that need to be supported at the early stages of team formation for innovation, and what tools can be used in facilitating these processes in a system.

Based on the relevant work presented in section 2, section 3 will define requirements for supporting team formation for innovation. Section 4 will present a tool developed within a UK project which aimed at Building Research and Innovation Networks (BRAIN). The BRAIN tool supports multidisciplinary team formation for innovation. Section 5 will discuss how user modelling, adaptation, and personalisation (UMAP) techniques can be incorporated in future work following BRAIN to better facilitate team formation. Section 6 will then conclude this paper.

2 Relevant Work

2.1 Social Processes Important for Team Formation for Innovation

The requirements and processes that need to be supported when forming a team depend strongly on the purpose of the prospective team. In this section we discuss social processes important for the formation of multidisciplinary teams for research innovation (i.e. creating new ideas or finding new solutions to challenging problems).

Mohammed and Dumville (2001) developed a framework pointing at the importance of the development of shared mental models, the facilitation of information sharing, and the support of transactive memory between team members [2]. This stressed the need for pulling information from multiple disciplines, and identified several crucial processes for successful teams. **Team mental models** provide members with a shared, organised understanding and mental representation of knowledge about key elements of the team's environment or topic of interest. **Information sharing** helps team members to shape and organise their ideas around a topic of common interest. Without information sharing the team cannot function and reach the required level of team (shared) mental models needed. Shared information can also help in reshaping the team when new ideas not previously known to the team come in for discussion. **Transactive memory** [3] concerns the members' awareness of what knowledge is possessed by whom in the team; and refers to members' ability to use peers' memory (expertise) as an extension of their own memory (expertise).

More recently, Paletz and Schunn (2010) have reviewed literature from psychology and social sciences with respect to multidisciplinary team formation for innovation and creativity purposes [4]. They propose a social-cognitive framework describing the social and cognitive processes important when a multidisciplinary team is formed for the purpose of innovation. The framework proposes two stages:

- **Stage 1: Divergent thinking** - which takes place at the formation of the team and involves pulling information and knowledge from multiple directions and various interpretations according to the members' own understanding of the topic;
- **Stage 2: Convergent thinking** - where members share the information and knowledge collected, discuss upon finding a common ground, and agree on what will be followed by the team.

Different social and cognitive processes are involved in each stage of this framework. At **Stage 1**, **knowledge diversity** is considered important and is associated with team innovation. Through this divergent thinking in interdisciplinary teams, discussions are generated which, in turn, increases the drive towards novelty and complex thinking. For this to happen though, the group should have sufficient participation in **information sharing**. At this stage peripheral members who hold unshared information play a vital role in the success of the team. Without enough participation and unique information to be shared within the group there will not be innovation. **Formal roles** within the team may concern expertise and/or power structures and enable **transactive memory** among members to be developed. Thus formal roles created in the team are influencing team discussion via their associated communication norms.

At **Stage 2**, the team narrows and selects options based on what has been brought in and discussed among the members. In this way, the team identifies the most promising ideas to be followed to achieve innovation. The development of **shared mental models** among members is vital, as members crate a common understanding of the ideas and processes involved and what has to be done to achieve the team's goal. **Knowledge diversity** also plays an important role here, in the sense that information from different disciplines must continue to flow in the team but at this point members should be able to interpret this information with a shared view.

Relevant reviews carried out in organisational psychology and team performance [3], [5], [6] confirm that **knowledge diversity** has been positively associated with team innovation at organisational level [7]. Similarly, **information sharing** among team members has proven to be very important for creativity and for generating discussions within the team [8]. Other important aspects identified include establishment of **formal roles** and development of team **transactive memory** [3].

The next section will discuss techniques that can be used in computer systems for supporting important processes for team formation for innovation.

2.2 Techniques to Support Team Formation for Innovation

Identifying, analysing and supporting collaborative innovation networks, is one of the key research areas relevant to team formation for innovation. There is not much work reported on this aspect, but the following approaches can be viewed as an initial attempt to build technologies for the above purpose.

Danowski [9] combines semantic text mining, social network metrics and visualisations in an attempt to identify collaborative innovation networks in an organization. In his paper the web is used to extract relevant documents about employees in a college department. The method of proximity co-occurrence indexing [10] is then used to extract **connections** between people based on department and relevant interests that appeared in the network. Standard **social network analysis** metrics (e.g. density, centrality) are used to obtain networks of similar actors, extract centrality measures and other quantitative similarity metrics. **Visualisations** combined with **statistical analysis** have been used in order for the networks to be externalised and the results of the constructed network presented to the team.

A similar approach is followed by Gloor et al. [11] where email and other computer logs are analysed in order for potential collaborative innovation networks to be identified and supported. Once the relationships (networks) are extracted (based on text mining), a **social network visualisation tool** is used to convey the network to the team. Since the results are directed graphs, density, betweenness centrality and group degree centrality metrics are used to analyse the extracted networks.

Concerning supporting innovation through team collaboration, Angehrn et al. have developed a tool using Web 2.0 technologies to support knowledge exchange, taking into account the social, emotional and psychological needs of individual team members [12]. The development of InnoTube took into consideration the elements of collaboration, knowledge sharing, reciprocal trust, recognised ownership, network visualisations, reinforcing and enlarging innovation stakeholders' networks. The purpose of this tool is to foster the creation of connections among community members, between members and content created, and stimulate participation. In order to achieve these, InnoTube is using the SLATES (Search, Links, Authorship, Tags, Extensions, Signals) paradigm[13]. It considers effective **search** as vital in supporting the creation of teams for innovation, as well as providing **visualisations and awareness techniques** with respect to relationships between actors and artefacts in the team/community. **Collaborative authorship** support tools are also important when participants are drafting reports/proposals together, as well as providing the option to use tags in associating the available content. Extensions, for example **recommendations** for further reading or relevant videos, are also a good complement when a member is looking at a specific artefact in the team's virtual space. These features were built and evaluated in a car manufacturing company. They were proved to improve the communication of ideas and were appreciated by the participants.

3 Essential Requirements and Processes for Supporting Team Formation for Innovation

The primary purpose of the above review was to inform the derivation of essential requirements and the identification of processes to be supported when forming teams for innovation. In this work, we focus on the formation of teams at their very early stage. Thus, following [4], we extracted processes and structures that need to be supported at this early stage of team formation[1]. The following processes and tools

[1] We acknowledge the importance of processes that need to be supported at a later stage, when the team has been formed and is functioning (shared mental models, trust etc.). However, our research focuses primarily the early stage of the team formation.

need to be kept in mind when new systems are developed aiming at providing support for team formation for innovation.

Social Processes:

Disciplinary and knowledge diversity: In order for innovation to be achieved and for members to creatively collaborate, different perspectives must come in place [4]. Consequently, members must have diverse backgrounds and bring in the team their own knowledge and point of view [3]. In this way, the team has a holistic viewpoint and with knowledge coming from different disciplines, problem solving becomes easier and prospects for innovation to be achieved increase.

Formal Roles: Power, knowledge and tasks roles have to be clearly defined in the team in order for members to have an understanding of what is expected of them as an input, and also to be able to identify who can be of help in the team if a situation arises [3], [4], [5], [6]. That is, if an expert is needed on a specific subject, members should be able to know who is holding that expertise in the team. This relates to transactive memory which is proven to be positively linked with the performance of a team [3]. Power roles are also important and need to be identified and supported early in the formation of the team [4]. For example, a team coordinator or facilitator responsible for organising the activities, tasks, and setting deadlines, needs to be clearly identifiable and known to team members.

Information Sharing: Sharing of information by all members is essential to ensure that information flows in the team, and perspectives from every discipline involved, are heard.

Enabling Technologies:

Search Tools (people and information): Searching for people who can compose a team and work on a specific project is very important process, should be supported. Similarly, searching for relevant reports, academic papers and other resources is equally important in order for someone to get an understanding of what the others in an organisation have been working on, and judge the relevance of their expertise to a current open call for an interdisciplinary project.

Connections/Relationships Discovery Tools: Members should be provided with the relevant tools to help with identifying connections and relationships that exist between team members, as well as other people in the network. In this way, composing a team of members who come from different disciplines but have common interests will be easier and more efficient.

Social Network Analysis Tools: Social network analysis allows for meaningful information to be extracted and similar groups of people to be identified within large networks of people. Possible similarities between people in the network can be identified to help with the team formation. Furthermore social network tools provide potential members with facilities to discuss, share thoughts, and in to an extent to collaborate by sharing resources and ideas in a common collaboration platform.

Visualisations: Visualisations can be used to provide static or dynamic images of connections and relationships between people either because of a similarity in interests, in research areas, or because they have previously collaborated or co-authored a paper. If a team needs to be formed for a given project, relevant people across the organisation will be discovered, and given the opportunity to join the team.

The next section will provide a brief description of how the BRAIN application, designed and built for supporting multidisciplinary team formation for innovation, took into consideration some of the processes and techniques discussed above.

4 The BRAIN Project and Tool

This work is carried out as part of the Building Research and Innovation Networks (BRAIN[2]) project, funded under the UK JISC Virtual Research Environments Programme. The BRAIN project aimed at facilitating the building of teams of researchers to enable the accumulation of collective intelligence and innovative outputs when participants from different areas engage in joint initiatives.

To illustrate the importance of BRAIN, we will consider two scenarios:

- Recently there was a research call funded jointly by the Science and Social Science Research Councils in the UK on the theme of “Energy and Communities”. The call involved subject areas ranging from environmental science, civil engineering and computer simulation through to psychology, sociology, economics and politics. A research institution wants to respond to the call by forming a multi-disciplinary team who will generate an innovative idea to be put in a joint proposal. The key challenge is to identify who should be involved, and what facilities would support the development of a proposal.
- A similar, but less clearly defined requirement arises when trying to identify groupings or clusters of researchers that may have the potential of working together or where the objective is to identify sub-disciplines within a larger area, but where the connecting themes are not known in advance. Examples concern finding connections between specific research groups and wider groupings of researchers for the purpose of the Research Evaluation Framework (a UK–based research assessment exercise that reviews research across higher institutions, and requires the institutions to present coherent research streams).

In order to meet the above scenarios and following the requirements outlined in Section 3, the BRAIN project developed a tool. It allowed us to evaluate and identify what more is needed by users who are involved in cases like those presented above. We will briefly outline next the BRAIN tool[3].

In the implementation phase of BRAIN, we wanted to include the basic functionality that required from a system to facilitate team formation for innovation (Fig 1). At first, the user is presented with the **user input panel** and is allowed to search for a topic, using *keyword search* or perform a *person search* through the data available. Data extracted from the **university databases**, describing researchers’ expertise, interests, publications and projects previously or currently working on.

---

[2] http://project-brain.org/

[3] A more detailed description of the system has been presented at [11].

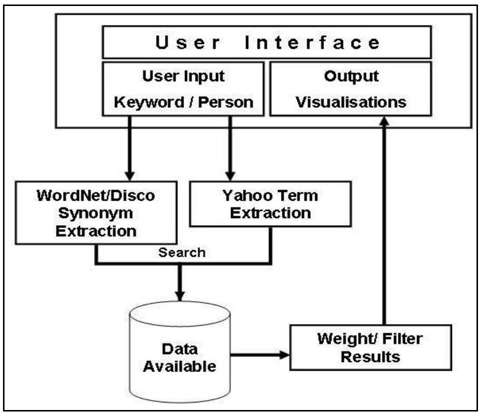

Fig. 1. The main components of the BRAIN tool and their interactions.

The **keyword search facility** implemented based on a simple string matching of the search word provided by the user, within the available data. Synonyms were then extracted using WordNet[4] and Disco[5] facilities and a checkbox facility provided for the user to choose a synonym according to preference. Selected synonyms were used for extracting commonalities between the keyword entered and the data at hand.

For the **person matching facility**, the Yahoo Term Extraction service[6] was used.

Filtering/weighting results is one of the components in determining commonality. This approach was not a necessity for the keyword search. However, for the person search this was an important consideration. Two techniques were used to tackle this problem. The first was the use of a stop list which filtered out certain words or phrases which were adjudged not to be useful in establishing connections, and was used after the stage of keyword expansion. For example, words like "research" and "university" are obviously too general to be used. The second technique used was to provide a user with a selectable filter parameter which would exclude terms which generated over a specified number of person matches. This allows searches to be run, and then this parameter adjusted depending on the results.

In this way, a user can became aware of his *similarities* with researchers from other *disciplines* with *diverse knowledge*. The system functionality allows the user to see the items responsible for a displayed connection. The output is stored in other formats that can be exported into other applications for analysis and **visualisation** (Fig 2).

The functionality of the system was evaluated continuously using personal interviews and focus groups allowing users to comment and advise us on what more was needed when forming teams. The next section will revisit the BRAIN tool using the processes and tools identified as important (Section 3). We will discuss what more can be done and how UMAP approaches can help in building systems, like the BRAIN too that facilitate multidisciplinary team formation for innovation.

[4] http://wordnet.princeton.edu/
[5] http://www.linguatools.de/disco/disco_en.html
[6] http://developer.yahoo.com/search/content/V1/termExtraction.html

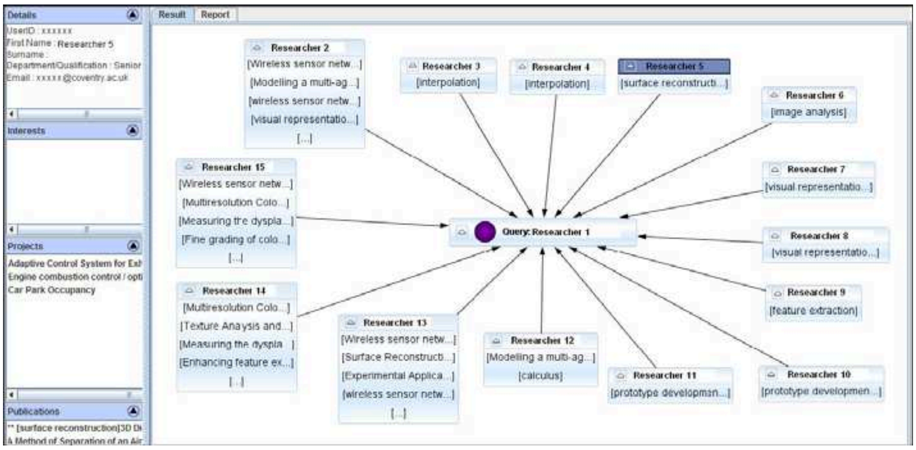

Fig. 2. Visualisation output of a typical person connection[7] search performed in BRAIN.

5 Future Extension of the BRAIN Tool

The process of forming a team of people who will collaborate and achieve innovation is very complex and needs to be carefully engineered. BRAIN attempted to address this problem by providing basic tools that allowed university academics to search and find information about colleagues who worked, or who are interested in specific areas and form teams. BRAIN provided support in the formation of team in terms of *knowledge diversity* by providing a **search tool** available to the interested parties that allowed searching based on key terms that represent specific research areas. This information has been presented as **graph visualisations** showing to people their *connections* with each other in terms of knowledge and interests. Although this can be considered as a first step towards supporting multidisciplinary team formation for innovation, more is needed for the support to be effective. An important lesson learned from the BRAIN evaluation is that people tend to remain focused on their everyday group interactions, failing to interact with, and bring, a different perspective in their research which might provide them with the added advantage and drive them closer to innovation.

Further extensions: User modelling, adaptation and personalisation techniques can be exploited to improve the effectiveness of the BRAIN tool. User models can be used to hold information about individuals that will be connected to, and automatically updated according to, the university's databases. **Open user models** [14] can be used allowing in this way individuals to view and edit their user model accordingly to ensure that up-to-date and accurate information is held by the system. Algorithms can be developed to enhance the existing search tools and allow to automatically extract **semantic connections** [15] based on the information stored in

[7] The names of the researchers returned as output have been removed and anonymised accordingly for data protection purposes.

the user model, and relevant to the knowledge and interests of a member. This tool will provide the backbone for **personalised notifications** [16, 17] to be generated, which will include information on connections, similarities or relations a member has with others in the network. These notifications can be sent to a given member if requested and allowing him to view the output in a **dynamic graph visualisation** [18]. Extended tools will allow a member to contact another member, if necessary, by clicking on that member's name in the graph.

According to the processes and tools discussed in section 3, once the relevant people have been identified, a **communication tool** [12] should be in place, synchronous and/or asynchronous, where people will be able to contact each other in order for a team to start forming. This is especially important since the team is interdisciplinary and members have diverse knowledge. Being able to discuss and argue upon different ideas and opinions will allow them to make better selection of the best ideas to take forward.

In order for collaboration to lead to the generation of innovative ideas, the team has to set *formal roles* [5], [6]. Each member must have a role based on knowledge, experience, or status and work on tasks relevant to this role. This can be done through internal team communication that requires input from all potential members. Knowing who knows what in the team and who can perform better in what task will allow the development of *transactive memory* and allow better collaboration to take place [3].

In supporting initial collaboration among the interested members, tools for *information/knowledge sharing* [2], [4] should be in place. **Adaptation techniques** can be utilised to allow members to view relevant information according their role and task in the team and allowing filtering out all the irrelevant activity, reducing in this way information overload. **Personalised awareness techniques** can be used to allow people to know what is happening in the team by choosing what activity they want to be aware of. **Personalised messages or visualisations** can be featured to provide this kind of awareness to team members.

The above techniques have already been implemented and their effectiveness has been evaluated in user-adaptive systems with different purposes. We argue that these techniques could be exploited for team collaboration for innovation, and corresponding evaluation studies should be conducted to evaluate the suitability of the tools in this application context.

6 Conclusions

The paper has identified what social sciences and psychology consider as important ingredients that can be supported in team formation for innovation. An attempt has been made by other systems, as well as the BRAIN project, to provide support to prospective teams of members that collaborate towards innovation. The paper points out that technologies have yet a lot more to offer. Using adaptation techniques for supporting multidisciplinary team formation for innovation is a research area, yet to be explored. There are opportunities for researchers to work and innovate by applying existing techniques to a new area that needs the vision, as well as the maturity of a technologically advanced domain like UMAP.

References

1. Gloor, P.: Swarm Creativity: Competitive Advantage through Collaborative Innovation Networks: Oxford University Press, USA (2006).
2. Mohammed, S. and Dumville, B.C.: Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries: Journal of Organizational Behavior. 22(2): p. 89 - 106 (2001).
3. Ilgen, D.R., et al.: Teams in Organizations: From Input - Process - Output Models to IMOI Models: Annual Review of Psychology February 2005(56): p. 517 - 543 (2005).
4. Paletz, S. and Schunn, C.: A Social-Cognitive Framework of Multidisciplinary Team Innovation: Topics in Cognitive Science. 2(1): p. 73-95 (2010).
5. Guzzo, R.A. and Dickson, M.W.: TEAMS IN ORGANIZATIONS: Recent Research on Performance and Effectiveness. p. 307-338 (1996).
6. Hage, J.T.: ORGANIZATIONAL INNOVATION AND ORGANIZATIONAL CHANGE. p. 597-622 (1999).
7. Bantel, K.A. and Jackson, S.E.: Top management and innovations in banking: Does composition of the top teams make a difference? p. 107 (1989).
8. Magjuka, R.J. and Baldwin, T.T.: Team-based employee involvement programs: effects of design and administration. p. 793 (1991).
9. Danowski, J.: Identifying Collaborative Innovation NetworksAt the Inter-Departmental Level: Social and Behavioral Sciences. 2(4): p. 6404-6417 (2010).
10. Danowski and J, A.: WORDiJ: a word-pair approach to information retrieval, Gaithersburg, MD, ETATS-UNIS: National Institute of Standards and Technology (1993).
11. Gloor, P.A., et al.: Visualization of Communication Patterns in Collaborative Innovation Networks - Analysis of Some W3C Working Groups, in Proceedings of the twelfth international conference on Information and knowledge management ACM: New Orleans, LA, USA (2003).
12. Angehrn, A., et al.: InnoTube: a video-based connection tool supporting collaborative innovation: Interactive Learning Environments. 17(3): p. 205-220 (2009).
13. McAfee, A.P.: Enterprise 2.0: the dawn of emergent collaboration: Engineering Management Review, IEEE. 34(3): p. 38-38 (2006).
14. Kay, J.: Accretion Representation for Scrutable Student Modeling, in Proceedings of the 5th International Conference on Intelligent Tutoring SystemsSpringer-Verlag (2000).
15. Kleanthous, S. and Dimitrova, V.: Modelling Semantic Relationships and Centrality to Facilitate Community Knowledge Sharing. in Proceedings of the 5th international conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH'08) Germany, LNCS Vol. 5149, 123-132 Springer Berlin / Heidelberg (2008).
16. Ardissono, L., et al.: Context-aware notification management in an integrated collaborative environment, in In Proceedings of International Workshop on Adaptation and Personalization for Web 2.0 (AP-Web 2.0 2009) at UMAP'09: Trento, Italy. p. 21 - 30 (2009).
17. Kleanthous Loizou, S.: Intelligent Support for Knowledge Sharing in Virtual Communities, in School of ComputingUniversity of Leeds: Leeds (2010).
18. Cheng, R. and Vassileva, J.: Design and evaluation of an adaptive incentive mechanism for sustained educational online communities: Journal of User Modeling and User Adaptive Interaction. V16(3): p. 321 - 348 (2006).