OPEN SOURCE HARDWARE COMMUNITIES: INVESTIGATING PARTICIPATION IN DESIGN ACTIVITIES

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ABSTRACT

Open source design of hardware products is an emerging phenomenon that takes more and more importance today's in the society. However, open source (hardware) design implies a tremendous change in both design practices and philosophy because it is partly related to the movements of creative commons and the sharing economy. From this perspective one could think that participation is crucial in the success of open source design projects. In this paper, we analyse 9 case studies in the light of 3 hypotheses. If many studies highlight the potential of the crowd as a resource for design tasks, our study shows that for open source design communities the participation is not massive. In this study, we used an activity-based approach to build our model. As open source design processes are fairly unstructured and based on voluntary participation, it is impossible to adopt a classical task-based model. With the help of this model, we were able evaluate the overall size of the active community, the participation rate with regards to the activities. This study paves the way to deeper and extensive studies on how to support communities engaged in open source design of hardware products.

Keywords: Open source design, Collaborative design, Open innovation, Design process, Organisation of product development

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1 INTRODUCTION

Open source design is a very common practice in software, while it remains marginal today in product design. Open source hardware as defined by the consortium of the Open Source Hardware Association[1] is an increasingly growing phenomenon that takes its roots in the makers' movement. In their paper entitled "what is the source of open source hardware" (Bonvoisin *et al*., 2017) studied 132 open source hardware products to come up with a series of criteria and rules to define the level of openness of these projects. According to Balka, Raasch, and Herstaatt (Balka *et al*., 2014), who distinguish accessibility, transparency and replicability as the three main characteristics of openness, Bonvoisin *et al*. showed that only a small fraction of the 132 projects were actually fully open in Balka and al.'s sense. These results encouraged us to investigate more on the actual design process in order to understand better the underlying mechanisms of open source product development (OSPD). More specifically as open source movement is mainly described as collaborative (if not fully opened) where the involvement of the participants is based on voluntary participation, self-selection of tasks and freedom to leave, it appears to us that a strong motivation should underpin the involvement of people in the OSPD projects. Are the OSPD projects so collaborative? Who is collaborating with whom? And what are the main channels of communication people are using to collaborate? Here are the main questions we address in this paper. Our main motivation is to distinguish fans who are following the news or are active on publicizing, commenting the project, and actors who really participate to the technical developments.

2 EVALUATING THE LEVEL OF COLLABORATION: A RESEARCH QUESTION

Design collaboration is an important topic of study as it has been recognised as one of the key success factors in design teams since a long time. Numerous studies have demonstrated the importance of collaboration and numerous tools today claim to foster collaboration in design teams. It is not our purpose here to cite them and we consider this as shared knowledge among the academic community. However, considering that collaboration automatically applies also to OSPD as a natural way to coordinate the activity is questionable. Firstly, because little number of studies actually focused on studying the design process of open source hardware products and secondly because a surprisingly large number of tools claim to support open source communities but little evidence of their use is shown by the stakeholders. Therefore, we will raise two research questions in this paper: Is OSPD so collaborative? And how is the participation structured along the design process? Recent work on open design have demonstrated some important differences between traditional industrial approach and the open design (Moritz *et al*., 2018). (Boisseau *et al*., 2018) showed that the roles of the participants in the design process tend to be less defined in open design processes, when, on the other hand, the design tasks remain the same (i.e. ideation, concept generation, system design, prototyping, etc.). Additionally as (Balka *et al*., 2009) showed, in most cases the size of the active community remains relatively small in early design phases. Our first hypothesis H1 is therefore: "core teams in early design phases are limited to a small number of actors". Crowdsourcing is very popular today in industry and particularly concerning ideation phases where social media tend to appear as potential interesting media to attract numerous contributors (Escandon-Quintanilla *et al*., 2015). Additionally, early works have also showed that contributions may drastically decrease after ideation phases on crowdsourcing platforms (Arikoglu *et al*., 2008). Open design may follow the same trend and therefore we can formulate our hypothesis H2: "number of contributors in ideation phase is larger than in other design activities". In this study, we are making a clear distinction between design phases and design activities. As many open design projects do not follow a very stable agenda and, as participation is on a voluntary basis, the pace of the project might sometimes be erratic, it is difficult to identify and analyse the contents of each phase. Additionally, as we saw previously, the roles of the participants are not clearly defined and may evolve along the process, which is another limiting factor to consider open design from the organisational point of view. Therefore, we prefer to adopt an activity perspective, as described in section 3, than a temporal one based on a design process model. This leads to our third hypothesis H3: "the participation rate varies depending on the design activities

[1] OSHA : Open Source Hardware Association (https://www.oshwa.org/)

and it is possible to identify patterns of involvements". In the next section, we will introduce our theoretical background and our research methodology.

3 METHODOLOGY AND DATA COLLECTION

The study relies on a sample of 9 OSPD projects that are analysed from semi-structured interviews of their core members. This section presents the data and the analysis method we used. We have selected core team members for these interviews in order to have a broad and comprehensive view on each project. We have interviewed one person per project and sometimes had to recontact them several times to complete the information as the principle of the interview were complex (see section 3.3.1).

3.1 Activity model

In order to characterize OSPD projects, we propose a simple activity model. The model is intended to identify the main activities carried out by the participants. It should be general enough to be used with each OSPD project. It should also be selective enough to highlight some differences between the organizational structures of the various OSPD projects. Since OSPD projects are driven by communities' participants, and the role of each individual remains generally very fuzzy, the activities in the model should be able to clearly reflect who is doing what within the design project.
Although we propose an activity model rather than a process, some activities of the model are in close relation with classic Design Thinking phases (Stanford d.school, 2010). Hence, our model distinguishes 5 fundamental activities related to OSPD projects. They are consistent with the Leontiev's activity theory (1981) (Hasan *et al*., 2014) and are defined as follows:

- **Ideation**: some community members take part in providing and sharing ideas. The ideation activity is when people propose and discuss radical design alternatives, either in the problem space (i.e. requirements, constraints) or in the solution space (i.e. concepts, product definition). Ideation places great emphasis on divergence and "going wide". Since this activity requires no specific skills and no complex tool or equipment, almost each community member should be able to take part. Typical actions linked with the ideation activity are: propose concept or generic idea, explain, draw or describe concept, chose the concept to develop.
- **Developing**: is the activity of defining the technical solution, of making the ideas exist in the virtual world (i.e. precise drawings, CAD models). Unlike the Ideation activity, the Developing activity places great emphasis on convergence and focusing in terms of concepts and outcomes. It requires technical and engineering design skills from the participants, who in addition, often use specific tools and software. Typical actions of Developing are: formalize technical problems, propose, chose or develop a technical solution, make a CAD model, write a documentation.
- **Prototyping**: making the ideas and solutions exist in the physical world is at the heart of the prototyping activity. Artefacts generated by this activity might be quick and cheap, then iteratively refined following progress of the design process. They can also focus on a specific solution feature or on the global product, aiming at testing either a specific requirement or the whole set of design constraints. Assessment of the prototype is full part of the activity. Manual skills are generally required for Prototyping, as well as a minimum of materials and equipment. Typical actions carried out in Prototyping are: make prototype, test prototype, analyse prototype, adjust prototype.
- **Producing**: again, the aim is here to make products exist in the real world. But unlike in the Prototyping activity, people engage in the Producing activity with the aim of making a usable product, for themselves or for a third party. Producing requires manual skills, and relies generally on more complex materials and equipment than Prototyping. Examples of typical Producing actions are: make the product, finish the product, adjust the product settings.
- **Using**: the ultimate goal of any product design initiative is to make it used by somebody. Product users are the ones that engage in the Using activity. A common feature of OSPD projects is that Using activities are carried out by a significant part of the community. Moreover, it is not unusual that community members design for themselves. In that case, user feedback is more easily collected by the project community and can feed any of the design activities.

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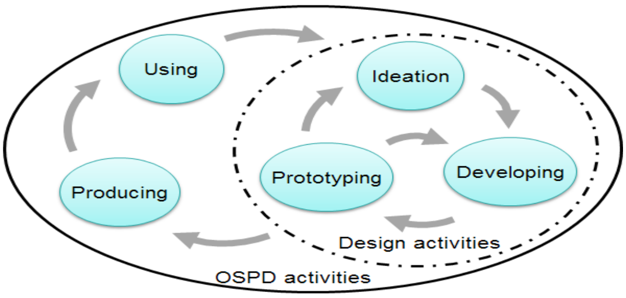

Figure 1. The proposed activity model

Figure 1 shows a graphical representation of the OSPD activities model. Three of them, Ideation, Developing and Prototyping are the design activities. During the design process, the activities follow one another in more or less complex loops suggested by the arrows.

3.2 Activity repartition model

We propose here a visual representation of the activity repartition. This model has two motivations. First it aims at facilitating interaction with the community members and improving awareness during the interviews, second it aims at visually representing the community structures in order to compare them. The circles are interwoven depending on the number of participants involved in the considered activities. One circle inside another indicates that all the participants of one activity participate to the other and that one activity involves more participants than the other. Two perfectly identical circles would indicate that the exact same people participate to the two activities. Additionally, the size of these circles is proportional to the number of participants (see figure 2).

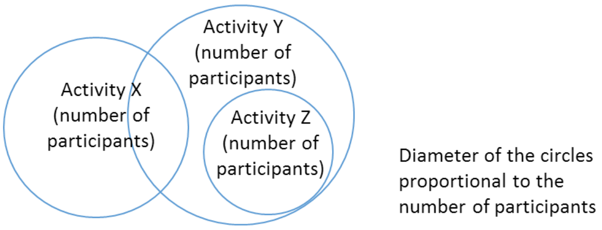

Figure 2. Surface of the circle proportional to the number of participants

3.3 Analysis method

3.3.1 Data

Semi directed interviews were conducted during spring 2018, and 9 projects responded to our interviews. For more information on the projects refer to the database[2] and projects' websites. Table 1 shows the name and Open O Meter score for each of those projects.

Table 1. Evaluation of the openness of our projects sample with Open O Meter (Bonvoisin and Mies, 2018)

	Entropie - Solar cooker	Log - Logresse	Circular Knitic	OSE - Tractor	echOpen	OSA-Ultrascope	Qrokee	Showerloop	Apertus Axiom
Open O Meter	1	7	6	2	6	7	0	6	5

We conducted the interviews via Skype, or by phone, and the circular diagrams used to structure the interview were shared simultaneously with the interviewee so that they could be amended in real time. Verbal exchange and data were recorded to avoid information lost.

[2] https://opensourcedesign.cc/observatory/

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We used a semi-structured questionnaire made of 3 parts:

- The aim was to precisely identify the number of participants in each activity, leading to co-construct the models presented in section 3.2. The focus was also to detect the potential intersections between the circles, i.e. how many people are engaged in multiple activities. This resulted in a figure showing up to five overlapping scaled circles.
- The second part addressed the different levels of involvement in each activity, i.e. define Core team, Active members and Peripheral members (Wenger, 1995). We also quantified each of these groups.
- Finally, the third part identified the actions in each activity and each group. Only the action of Decision making (Ideation activity) will be discussed in this paper.

3.3.2 Visual analysis

As seen in section 3.2 the visual model had two objectives. After the interviews, each activity repartition model was validated by the interviewees and then analysed visually. The analysis was qualitative and relied on the interviews as well as on the diagram analysis. Computer aided analysis is not necessary due to the small sample size.

3.3.3 Statistical analysis

For each project, we used statistical analysis to define:

- The level of participation defined as the number of participants in the design activities, to the total size of social media community.
- The participation rate in each activity (expressed in percentage) defined as the number of participants in the activity, to the number of active people within the design community.

4 RESULTS

4.1 Design communities and social media

In order to evaluate the relative importance of the design community with regard to the social media we have counted the number of participants in the design process of a given project (those involved in the design activities we have identified) and the number of followers of the same project on social media (e.g. Facebook or Twitter).

Table 2 shows the level of participation: the relative size of the design community compared to the one on social media. This figure shows that except for echOpen (10%), the level of participation of other projects is far under 2%, which indicates clearly that the active community is actually very small compared to the followers. We validate H1 hypothesis: *"core teams in early design phases are limited to a small number of actors"*.

Table 2. Design community vs. social media community

	Entropy - Solar cooker	Log - Logresse	Circular Knitic	OSE - Tractor	echOpen	OSA - Ultrascope	Qrokee	Showerloop	Apertus Axiom
Social media community	1500	582	577	72000	1000	1450	538	868	6000
Design community	6	9	3	35	100	9	3	6	15
Level of participation	0.4%	1.54%	0.53%	0.05%	10%	0.62%	0.55%	0.69%	0.25%

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4.2 Participation and task allocation in design communities

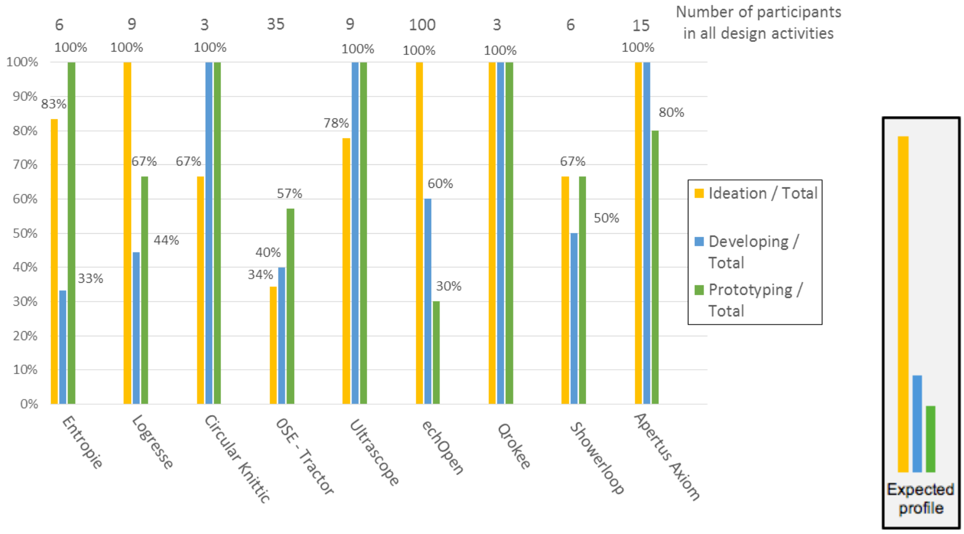

Figure 3. Participation rate in the three design activities

Here we are expecting a profile of participation where ideation is significantly higher than the two other activities and developing is a bit more important than prototyping. Figure 3 right displays the ideal profile. Only echOpen fits to this profile and Logresse, showing significant higher participation rate in ideation, could also partly fits the profile. However we see that all the other projects show a significant diversity of response. In most cases, the ideation activity is not prevalent therefore hypothesis 2 cannot be validated here. It seems that participation rates in each activity for each project are unique. There is no typical distribution of participation on the three main activities (Figure 3). Figure 4 shows the participation rate against number of participants for Ideation activity. The echOpen project appears very singular on this graph, involving a wide community of around 100 participants, and all of them are considered as participating in the ideation activity. This community is structured around a strong force of innovation, the product is technically highly complex, and participants are specialists of a wide variety of scientific fields, each one being able to propose innovative ideas from his/her expertise. The second singularity is OSE that has a low number of ideation participants, representing only 35% of the global design force. This can be explained by a high turnover of participants in the project, leading to difficulties for new comers to setup innovation proposals.

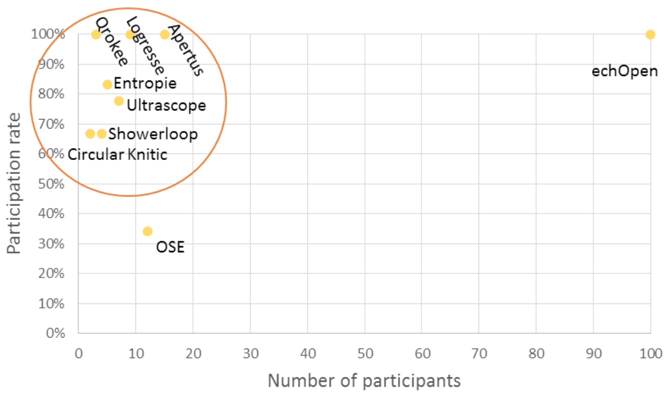

Figure 4. Participation rate in Ideation activity

Figure 5 shows the participation rate in Developing activity of these projects, and they can be classified into two groups. In the first one, every member participate in developing activities, considered as "developers communities", where even users are developers. In the second one, including echOpen, relatively low number of members participate in developing activities.

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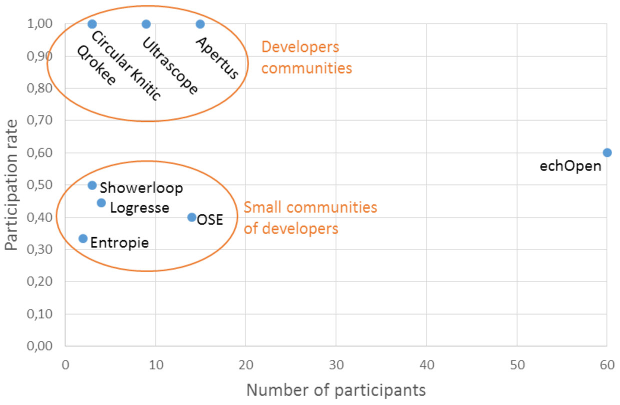

Figure 5. Participation rate in Developing activity

As for Prototyping activities, the projects are widely spread over the graph in terms of number of involved members, shown in figure 6. EchOpen still has the biggest absolute number of participants in prototyping due to the actual size of the community, but representing the smallest ratio, only 30% of prototyping members in the community. Apart of this, a group of 3 projects appears with a full community involvement in prototyping. This is probably enabled by the simple and accessible prototyping technologies used in these projects (mainly 3D printing, plastic or wooden sheet laser cutting, screws, and Arduino electronics).

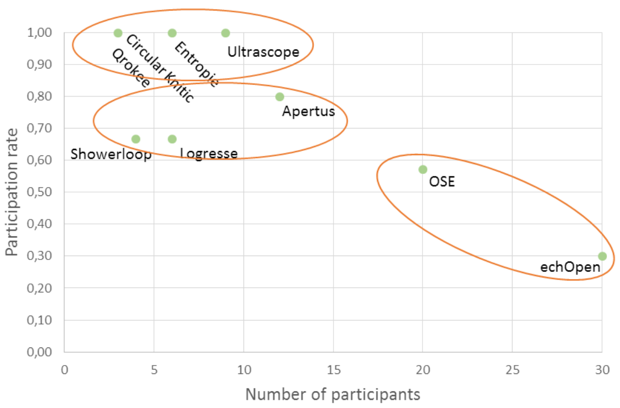

Figure 6. Participation rate in Prototyping activity

Then the other projects feature a medium to high (57% to 80%) involvement of members in prototyping. Again, this is directly related to the recent and rapid evolution of prototyping technologies, both for mechanical and control aspects, and this probably explains the recent development of OSH projects. OSE and echOpen feature the lowest participation rates for prototyping probably due to the high community size, but also to the higher level of complexity and variety in required technologies.

4.3 Patterns of activities

We present in this section the three main patterns we could identify to respond our third hypothesis H3: "the participation rate varies depending on the design activities and it is possible to identify patterns of involvements".

4.3.1 Most of the participants involved in the 3 design activities

Coincident pattern shows a well-balanced implication of the participants with mixed activities. It is a relatively integrated structure where most of the participants are involved in all the activities. The majority of the active persons is involved in each activity, or at least the core group is involved in all the activities.

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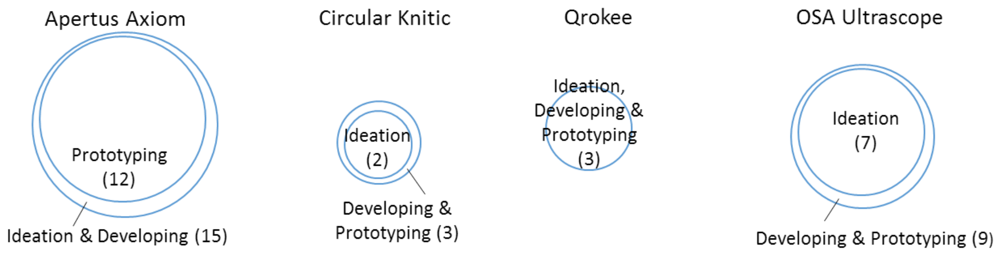

Figure 7. Integrated structure

4.3.2 Most of the participants involved in 2 of the design activities

In this configuration, the participants are mainly involved in two activities and one activity remains achieved by a smaller number of persons. It is not a fully integrated structure as the majority of the participants are involved only in 2 activities. This pattern is characterized by the predominance of one activity in term of number of participants.

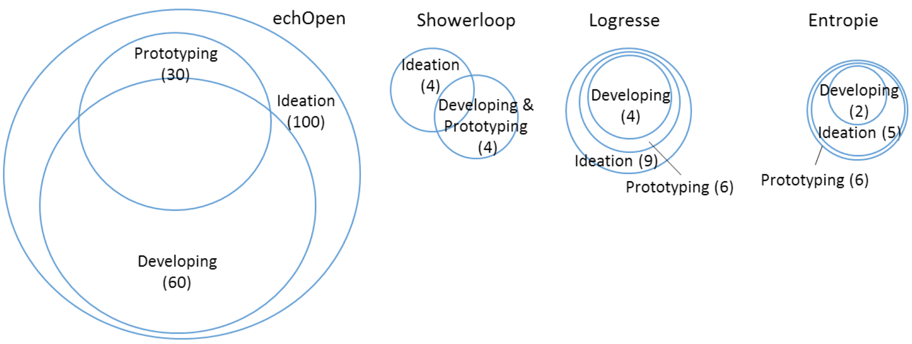

Figure 8. Mixed structure

4.3.3 Most of the participants involved in a single design activity

This pattern describes a community where three distinct groups achieve the different design tasks. The overlapping between the groups is not prevalent, on the contrary to that of other patterns. Therefore, it is clear to make the distinction between Ideation group, a Developing group and Prototyping group. This configuration is not common in our observation, however it is interesting to mention it, as this configuration copies the traditional industrial distribution of tasks in the design process where distinct people in the organisation perform different activities.

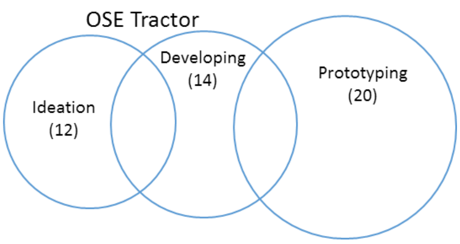

Figure 9. Distributed structure (OS tractor case)

The occurrence of these patterns is mainly based on opportunistic factors, especially the availability of people and their motivation to participate. The identification of these three circles configurations validates the hypothesis H3, i.e. existence of patterns of participation distribution in activities.

5 SUPPLEMENTARY FINDINGS

5.1 Size of the community

(Balka *et al.*, 2009) showed that the size of the community tends to increase with the product maturity level. In their observations, the core team size of a project in its early phase ranges from 1 to 10 core

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members, when those in commercialisation phase could reach a hundred of people. This is in line with our findings as the projects we considered in this study are in an early phase (they only reached the working prototype phase for the most advanced ones). There is certainly a threshold or a moment when the product becomes mature enough to disseminate and reach a level of popularity that allows massive involvement of a wider community, especially regarding production, usage and testing.

5.2 Decision making

Decision-making is a tricky task in open design, as there is no formal hierarchy, procedures or rules, binding the actors in a clear process. We often use the term "do-ocracy" to describe this type of decision-making process, i.e. the one that has the knowledge, skills, and that actually performs the task, is the decision maker. We found a more diverse situation in our cases.

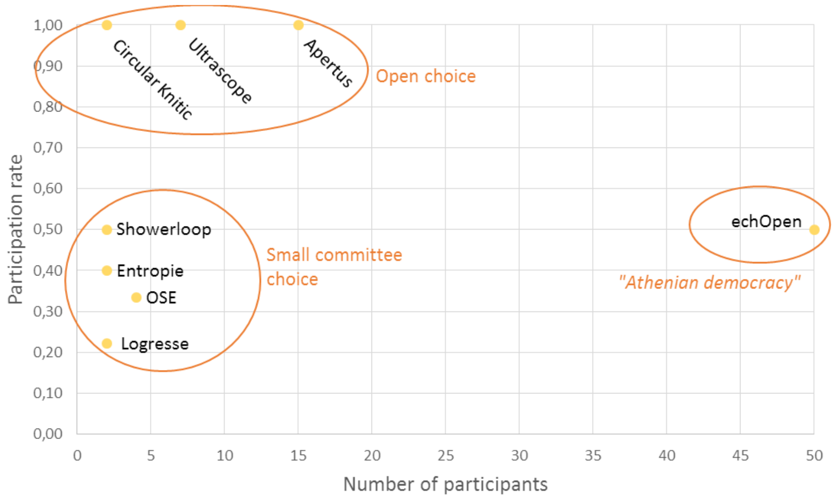

Figure 10. Decision making styles

Figure 10 shows three different decision making styles. "Open choice" (3 projects) means that all the participants who make propositions participate in decision making. This is the most collective decision making style and applies easily for small groups. "Small committee choice" at the opposite restricts the number of decision makers to 1 or the core team limited to few individuals (4 projects). This applies to bigger projects where the core team is strong. "Athenian democracy" (1 project) could deserve further research as the echOpen project is structured in smaller sub-projects where decisions are made locally. This appears to be a distributed decision making process where responsibility is delegated in each sub-project.

6 CONCLUSION AND FUTURE WORK

This work is part of a wider project funded by French ANR agency and German DFG that aims to understand and to support communities of open source hardware developers. In this paper, we analysed the characteristics of several open design communities through an activity-based approach. An activity model allowed was developed to highlight the relative importance specific activities and the size of the communities that are actually active. This study shows that, contrary to what is usually presented on community-based studies, the active core team is relatively small even for established projects. Consequently, researchers should make the clear distinction between participants of contests, like crowdfunding campaigns or projects fans on Facebook, and developers who actively develop solution and technologies. Additionally, we showed that there is no standard practice and organisation in Open Source Product Development, and further research is needed to identify the profiles of the participants, their motivation and propose a standard for open source hardware development.

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