

EVALUATING CITIZEN SCIENCE INITIATIVES THROUGH A CITIZEN SCIENCE-BASED APPROACH

PRAXIS
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ABSTRACT

Citizen Science (CS) has gained increased recognition over the last two decades. This turn is occurring in strong connection with the profound transformations that have affected science over the last few decades, leading towards a new social model of science, characterised by greater openness to society regarding research content, actors involved, research processes, and expected societal and economic impact. CS is at the centre of this complex change dynamics as a tool that strongly sustains the shift towards the “open social model” of science, supporting a new approach to the science-society relationship. However, CS is rarely evaluated for its long-term structural effects on science and the science-society relationship. This article addresses this topic, having as a point of departure the ongoing EC-funded Step Change project, aimed at promoting five Citizen Science Initiatives (CSIs) in different research fields (health, energy, and environment). Under the project, an Evaluation Framework has been developed, shaping the evaluation process as a citizen science project by adopting a developmental and participatory approach. The Evaluation Framework is organised into two different but intertwined levels, one focused on the evaluation of the individual CSI (analytical level) and a second aimed at identifying recurrent patterns of obstacles, facilitating factors, or a mix of them (neutral situations) across the CSIs (cross-cutting level). While the analytical level is intended as a service to better implement the CSIs, the cross-cutting level is intended as a research process to generate new knowledge on how CS could serve as a tool for a better anchorage of science into society.

INTRODUCTION

Citizen Science (CS) has seen a “new dawn” in the last two decades (Silvertown, 2009), as witnessed by, e.g., the rapid diffusion of CS projects in different research fields (Cooper, 2016; Kullenberg, & Kasperowski, 2016) or the launch of national and European programmes in support of CS (Kieslinger, et al., 2018; Trojan, Schade, Lemmens, & Frantál, 2019).

This turn is connected to the profound changes affecting science in late modern society that have been the subject of various interpretative

models, including, e.g., the Mode 1 - Mode 2 model (Nowotny, Scott, & Gibbons, 2001), or the Post-academic Science (Ziman, 2000). Overall, these models describe a still ongoing paradigm shift from the consolidated social model of science – often associated with the image of the “ivory tower” – in which science enjoyed an exclusive authority in validating scientific knowledge and a high level of autonomy from the rest of society, to a new “open social model” in which science is engaged to match the expectations, needs, worries and problems of society, is transparent and responsible for the potential and actual use of scientific products, and is open to the cooperation with (and is also strongly dependent on) political, economic, and societal stakeholders.

Different strategies have been developed to propel, speed up, or manage this shift, including the adoption of a neoliberal reorganisation of research systems (Morrish, 2020; Troiani, & Dutson, 2021) and the development of responsible research and innovation policies (Von Schomberg, 2013; Stilgoe, Owen, & Macnaghten, 2013).

CS is at the very centre of this complex dynamics as a tool sustaining the shift towards the new social model of science, especially for the capacity to develop participatory and communication mechanisms (Woolley, et al., 2016) able to favour a “democratization of science” (Haklay, 2015; Strasser, et al., 2019).

However, the contribution of CS to orienting a new social model of science – i.e., its systemic impacts on science – is far from being evident. There are serious barriers to making CS a business-as-usual approach in R&I and little attention has been given to its potential structural effects on science and science-society relationships. This is also because the same concept of CS includes a wide variety of practices (Wiggins, & Crowston, 2011; Shirk, et al., 2012; Schaefer, & Kieslinger, 2016) with highly variable potential impacts.

This article aims at contributing to the reflection on this topic, having as a point of departure the evaluation framework developed under the ongoing EC-funded Step Change project¹. The manuscript comprises four main sections, respectively devoted to a short presentation of the Step Change project, the concepts, and assumptions at the basis of the evaluation framework adopted, the structure of the evaluation framework, and a discussion about critical aspects and limits of the proposed approach.

THE PROJECT AND ITS RATIONALE

Step Change is a 3-year long project led by the University of Primorska (Slovenia). It started in April 2021 and involves five CS Initiatives (CSIs) in different research fields (health, energy, and environment) to be held in five countries (Germany, Italy, Slovenia, the United Kingdom, and Uganda).

The project assumes that science always entails the involvement of laypeople and therefore “non-technical” knowledge (Knorr-Cetina, 1982) and the co-existence of different standpoints, no one of which is more objective than others (Harding, 1992). The need to fruitfully coordinate them dramatically increases when the scientific effort – as growingly occurs in contemporary science (Nowotny, Scott, and Gibbons, 2001) – is aimed at addressing the critical fields where human and non-human factors are deeply entangled (environment, health, artificial intelligence, biotechnology, etc.) and where highly contested social issues emerge. In such cases, incorporating the standpoint of social actors, especially marginalised people (Harding, 1992), is essential to capture aspects of the situation that otherwise could escape from scientific analysis.

However, the recognition of the presence of different standpoints does not imply that “objective” knowledge is impossible (Rolin, 2020). Rather, it implies that objective knowledge is closely dependent on increased control over the transepistemic dynamics embedded into the social relationships established around and within the research process.

In this framework, CS can play a structural role in the way R&I is implemented. Differently from other participatory approaches in research, CS is explicitly intended to influence the most intimate mechanisms of science (its practices and contents), with strong implications at an epistemic level (use of non-scientific knowledge to enhance scientific products), societal level (interactions between scientists and laypeople; social impact of scientific research), and institutional level (CS-related changes in research organisations and other involved organisations). These features make CS one of the few research approaches that are aware of the transepistemic dynamics of science and able to manage the power relations, bias and tensions connected with them. Moreover, they also show how much CS is connected and partially overlapped with the principles and practices of participatory action research (Albert et al. 2021).

However, a question that still needs to be investigated is whether and under what conditions CS can have a systemic impact on science and help manage the transition to a new social model of science. Indeed, the risk is to consider CS as a specific research approach that has no relation with and influence on conventional research practices and policies as well as science-society relations.

It is precisely this potential role of CS that the Step Change project aims to explore. For this reason, the project is developed along two parallel axes. The first axis focuses on the design and implementation of the five CSIs, while the second axis focuses on citizen science itself.

BASIC ASSUMPTIONS OF THE EVALUATION PROCESSES

The evaluation process, under Step Change, is based on these same axes.

On the one side, it is conceived to support the teams in charge of the CSIs to assess their initiatives. To this aim, the developmental evalu-

ation approach (Patton, 2010; Gamble, 2008; Preskill, & Beer, 2012) is used, since such an approach has some features which particularly fit CS projects.

- It is conceived to evaluate complex social interventions with a high level of uncertainty (and quite often CS projects are complex social interventions)
- It is not judgmental but aimed at providing the teams with proactive support during the implementation process
- It is highly participatory, fully involving the project teams in the evaluation process
- It is focused on the social processes underlying the project to identify and anticipate possible risks, rather than on recording the gap between a set of established ex-ante objectives or criteria and the actual ex-post project outcomes.

On the other hand, evaluation is understood as a powerful research approach (Byrne, 2013) to generate new knowledge about the dynamics related to CS and, more specifically, the extent to which and conditions under which CS can be a tool for socializing science (Bijker, & d’Andrea, 2009; Wyatt, 2009), that is, fostering a stable anchoring of science in society in terms of knowledge production, social interactions and institutional changes, as well as supporting the transition to an open social model of science.

These two components make the evaluation itself a citizen science initiative. Thus, evaluation is no longer only an organisational function, but also a research exercise, requiring the involvement of professional and non-professional evaluators (citizen scientists and other stakeholders involved in the CSIs).

THE STRUCTURE AND CONTENTS OF THE EVALUATION FRAMEWORK

To address this double need – supporting CSI teams and generating new knowledge on CS – an Evaluation Framework has been developed organised into two levels, i.e., an analytical level and a cross-cutting level.

ANALYTICAL LEVEL

The analytical level focuses on the individual CSI and is intended to allow the timely collection of relevant information and data to sustain the CSI teams in carrying out their activities, according to the principles of the developmental evaluation mentioned above.

Following Kieslinger et al. (2018), the analytical level includes three dimensions, i.e., the scientific dimension, the citizen science process, and the socio-ecological and economic dimension. Each dimension is assessed in terms of processes and outcomes and is organised in observation areas including a set of issues, presented in the form of questions.

- The scientific dimension focuses on the research and innovation processes of CSIs from the diverse perspectives of professional scientists and citizen scientists.
- The dimension of the citizen science process focuses on the participatory process characterising the CS approach.
- The social-ecological and economic dimension refers to processes and impacts of any kind the CSIs have, primarily at the local level, with special reference to the social sector the CSIs are focused on (e.g., health, energy, etc.).

The model of Kieslinger et al. (2018) was chosen for different reasons.

- It systematically addresses the three areas in which CS is believed to provide an added value in comparison to conventional research approaches by generating equally robust but more socially contextualised scientific results; fostering the involvement of stakeholders in both the research process and contents; and producing wider and faster social and economic impacts.
- It considers both the processes and the results of CS projects, giving the CSI teams the possibility to promptly adjust the processes to attain the expected results.

- The model is open enough to be customised to the features of each CSI. Thus, some observation areas have been adapted, some were eliminated as not relevant to the specific CSIs, and others have been added.

In the table below, the observation areas considered in each dimension are listed. The letter A, in the bracket, refers to observation areas added to the model of Kieslinger, et al. (2018). Although autonomous, the three dimensions are connected and partially overlapping.

Table 1. Observation areas included in the analytical level

SCIENTIFIC DIMENSION (SCD)	CITIZEN SCIENCE PROCESS (CSP)	SOCIO-ECOLOGICAL AND ECONOMIC DIMENSION (SED)
Process and feasibility	Process and feasibility	Process and feasibility
Evaluation mechanisms of the scientific dimension	Alignment of the CSI with the target groups and stakeholders	Target groups' alignment and active involvement of external actors
Adaptive project management	Degree of participation intensity of citizen scientists in the CSI	Collaboration and synergies with media and external CSO
Collaboration and synergies with other research groups in the same or other areas	Communication of scientific results and collaboration between professional and citizen scientists	Presence of evaluation mechanisms of the socio-ecological and economic dimension (A)
Match with planned actions (A)	Feedback to citizen scientists about research, societal, and policy outcomes of the CSI (A)	
Consideration of legal and ethical issues	Acknowledgement of citizen scientists (A)	
Financial and organisational issues (A)	Presence of evaluation mechanisms in the citizen science process (A)	
Outcome and impact	Outcome and impact	Outcome and impact
Exploitation of the scientific knowledge and publications	Learning outcomes for the participants (new skills, new competencies, etc.)	Impacts of the CSI in terms of increased social and political participation
New fields of research and research structures	Outcomes in terms of science literacy of participants	Satisfaction of external stakeholders and political actors (A)
Use of local knowledge resources	Outcomes in terms of behavioural changes of participants	Environmental impacts
Benefits for both professional and citizen scientists (A)	Participants' motivation and engagement levels	Generation of new technologies
Recognition of the limits of CS (A)	Matching with the planned targets (A)	Generation of new social innovation and practice
Satisfaction of professional scientists (A)	Satisfaction of the citizen scientists (A)	Generation of economic impacts and market opportunities

The analysis of each dimension allows drawing a profile of the CSI and thus detecting possible unbalances. For example, in some CSIs, the scientific dimension is stronger than the citizen science processes while in others the opposite occurs. Unbalances can be due to multiple factors, including the nature of the entity promoting the CSI (academic entity or civil society organisation), or the objectives pursued (predominantly scientific or predominantly oriented to social change).

Based on the Step Change experience, the choice of the teams to privilege one dimension over the others seems only partially intentional,

indeed it is also based on implicit assumptions or orientations. Thanks to the evaluation process, the teams could reflect on issues they would not have considered and modify or confirm their deliberate choices.

The information produced through the analytical level mainly concerns obstacles and constraints hindering the implementation of the CSI, opportunities and action strategies aiming to face them, and the results of such actions. An additional effort has been made to anticipate future critical steps and to reframe the situation when the actions carried out do not produce the expected output. Most of the information is collected

in the form of narratives and short texts, although specific quantitative data are also gathered. Special attention is devoted to the interaction between the involved actors (possible conflicts, tensions, coordination level), and the cognitive and emotional aspects (level of satisfaction, sense of ownership, motivations, etc.). Although a flexible approach to planning is applied, the organisational and planning-related aspects (match of the deadlines, match of the planned targets, management of the actions, etc.) are duly considered.

The analytical level is expected to provide the CSI teams with support to:

- Manage the CSI, especially for those aspects the team is less prepared to face
- Anticipate critical steps
- Develop alternative solutions when the original ones turn out to be ineffective
- Exploit the results of the CSI in terms of scientific and social impacts.

CROSS-CUTTING LEVEL

The cross-cutting level is not focused on the individual CSI but aims at identifying recurrent patterns across the CSIs, including patterns of obstacles, facilitating factors, or a mix of them (neutral situations). The underlying idea is that, although the CSIs are different from each other, the evaluation exercise can single out recurrent dynamics strongly connected to the specific nature of the CS and provide new insights into how CS could serve as a tool for socialising science, favouring a better anchorage of science into society.

In this perspective, the analysis can only be qualitative. However, since it is based on an in-depth observation of five different CS projects, it can nevertheless provide useful information to better understand the potential and limitations of CS as a tool for triggering structural changes, i.e., changes that modify relevant aspects (for example, organisational chart, norms and procedures, common practices, relations with external or internal actors, languages and symbols, etc.) of concerned organisations (research institutions, stakeholder organisations, public authorities, etc.) or research systems.

At the cross-cutting level, three components have been identified, each one focusing on different kinds of anchorage of science into society. They can be respectively referred to as the transepistemic, the societal, and the institutional anchorage.

Transepistemic anchorage concerns the capacity of CS to combine scientific knowledge with other kinds of knowledge (e.g., political, experiential, activist, traditional knowledge), preventing clashes and knowledge marginalisation (Knorr-Cetina, 1982).

Societal anchorage refers to the cooperation between citizens (non-professional scientists, stakeholders, policy actors, etc.) and professional scientists.

Institutional anchorage refers to the capacity of CS to activate institutional change processes in the concerned organisations (especially as regards the research).

The observation areas included in each dimension are listed in the table below.

Table 2. Observation areas included in the cross-cutting level

TRANSEPISTEMIC ANCHORAGE	SOCIAL ANCHORAGE	INSTITUTIONAL ANCHORAGE
Recognition of the knowledge produced by citizen scientists, stakeholders, and other actors	Mobilisation of stakeholders, other actors, and marginalised groups, in the CSI	Symbolic layer (changes in the visibility and representation of CS within the organisations involved with the CSI)
Actual use of the knowledge produced by citizen scientists, stakeholders, and other actors in the research process	Contextualisation of the CSI (in terms of problems, conflicts, policies, the influence of the social context on the CSI objectives and methods, etc.)	Interpretive layer (changes in the interpretation of CS within the organisations involved with the CSI)
Management of the trans-epistemic knowledge (communication, exchange of experience, knowledge sharing mechanisms, learning processes)	Application and dissemination of the outputs of the CSI (new knowledge, products, solutions, etc.)	Normative layer (normative changes triggered within the organisations involved with the CSI)
		Operational layer (changes in practices, skills, tools, projects, and methods within the organisations involved with the CSI)

The model has been developed using different sources.

The first component (Transepistemic anchorage) is based on a simplified interpretation of the model developed by Probst (1998), of the building blocks of knowledge management. It was chosen since it allows the recognition of the many processes and obstacles characterising the identification, brokering, sharing, and actual exploitation of knowledge of different types where different groups are involved.

The second (Social anchorage) and the third component (Institutional anchorage) are both based on the model of institutional change developed by Kalpazidou Schmidt, & Cacace (2019).

These authors identify four key steps of the institutional changes, i.e.,

- The creation of the group of actors able to activate the change (corresponding in many cases to the CS project team)
- The mobilisation of the social actors (mobilisation of stakeholders)
- The friction of the actions implemented by these actors on the existing structures (contextualisation process)
- The actual change of existing structures (application and dissemination of the outputs of the CSI).

The same authors also distinguish four dimensions of the institutional change process which have been applied to the component of the institutional anchorage.

- The symbolic layer concerns the image of the proposed changes (in this case, changes in the way in which CS is perceived, in terms of visibility and relevance)
- The interpretive layer concerns the interpretation of the proposed changes (in this case, the interpretation of CS as an approach that can improve the quality of science and its impact)
- The normative layer concerns the introduction of new norms, in a broad sense (new organisational units, new regulations, new standards, new procedures, etc.) that allow the change to occur
- The operational layer concerns the actual implementation and diffusion of the proposed change (in this case, making CS a business-as-usual approach).

These models do not necessarily reflect how changes occur but provide useful coordinates for capturing the dynamics of change when they occur.

The three forms of anchorage are intertwined. The transepistemic anchorage is likely the most peculiar feature of CS, distinguishing it from other forms of citizens' participation and especially from other approaches to scientific knowledge production. If the knowledge produced by or with laypeople is not recognized, used, or properly managed, the epistemological impact of CS simply disappears.

However, a good transepistemic anchorage is possible only when citizen scientists, professional scientists, and their institutions work well together. Thus, the quality of social anchorage processes becomes pivotal. In turn, both forms of anchorage risk being not sustainable and scarcely impactful if the institutional anchorage process fails to occur, i.e., if organisational learning processes do not start.

Based on some preliminary findings of Step Change, some factors seem to hinder or slow down the activation of the cross-cutting level.

- CSI teams are more interested in and engaged with the analytical level rather than the cross-cutting one.
- It is not always easy to transfer to the CSI teams the concepts and the theoretical assumptions on which the cross-cutting level is based, even though the Evaluation Framework has been discussed and modified based on inputs from the same teams.
- The implementation of the cross-cutting level requires exchange mechanisms involving all the CSI teams, while this is not necessary for applying the analytical level.
- The cross-cutting level can be started only in a later stage of the development of the CSIs, entailing changes in already consolidated procedures.

However, there are some immediate potential benefits deriving from the application of the cross-cutting level.

- It becomes possible to distinguish in any CSI what is "fully local" and what is simply a "local variation" of recurring CS-

related dynamics. This favours the teams in finding solutions already tested elsewhere.

- The cross-cutting level pushes CSI teams to go beyond their project to reflect on its long-term possible impacts on science practices and organisational changes at the local level.
- The cross-cutting level helps participants become more aware of the potential, limits, benefits, and risks of CS, thus overcoming simplistic views and stereotypes.

INTERACTION BETWEEN THE TWO LEVELS

The analytical level and the cross-cutting level are intertwined.

Most data are used twice, once for evaluating and supporting the individual CSI and once, in a different way, for identifying recurrent patterns and dynamics across the CSIs. In such a perspective, the cross-cutting level can be considered as a second-tier interpretation of the data and information produced under the analytical level.

The output of the cross-cutting level can help better understand the experience of each CSI at the analytical level, creating a sort of "feedback loop" between the two levels.

METHODOLOGICAL TOOLS

To activate and implement the evaluation framework, some methodological tools have been put in place. Since the evaluation process is still ongoing, only partial information can be given about the constraints met in applying it.

Firstly, five Local Evaluation Units – one for each CSI – have been established, made up of non-professional evaluators and stakeholders' representatives. In turn, each Local Evaluation Unit works in cooperation with a Central Evaluation Unit, made up of professional evaluators.

The Local Evaluation Units are established autonomously by the different CSI teams, involving professional and citizen scientists and, when possible, stakeholders. The unit members remain part of the CSI team and fully participate in its activities. However, they play an additional role, i.e., recording the most relevant facts occurring during the implementation of the CSI (for example, by filling in a diary) and elaborating their view about the development of the CSI, which are shared with the Central Evaluation Unit but especially with the rest of the team.

This organisational scheme has some advantages (ensuring the continuity of the evaluation process; ensuring a strong involvement of CSI teams throughout the project) but its application can also meet some obstacles.

- CSI teams include few people, thus identifying a sub-group of them specifically involved in the evaluation process can be problematic.
- CSI team members who are not part of the Local Evaluation Unit may feel marginalized.
- It is difficult to involve representatives of stakeholders in the evaluation process.
- The involvement of the Local Evaluation Unit in the application of both the analytical and the cross-cutting levels could be too demanding.
- Finally, a turnover of citizen scientists is highly probable (each CSI lasts around two years); and this could also affect the continuity of the evaluation work.

While at the analytical level the Central Evaluation Unit bilaterally interacts with each Local Evaluation Unit, at the cross-cutting level Local Evaluation Units and the Central Evaluation Unit work together as a single research team.

Secondly, a process of customisation of the Evaluation framework was carried out to adapt it to the specific features of each CSI and its context (normative context, policy context, research context, etc.). The principle is that evaluation can develop useful knowledge only if the causal power of context is recognised (Byrne, 2013), considering local factors and emerging dynamics (Kalpazidou Schmidt, & Cacace, 2017; Kalpazidou Schmidt, & Graversen, 2020).

The first step has been the organisation of five Customisation Workshops, one for each CSI. Every issue included in the analytical level has been scrutinised to identify their conditions of application, taking into consideration both the contents of the CSI and the context in which the CSI is developed. This exercise led to discarding the issues that turned out to be not relevant to the CSI and identifying those crucial for its development.

Other customisation initiatives are planned since some of the issues (for example, those about the impact) become relevant only in a later stage of the CSI.

Thirdly, following the tenets of developmental evaluation, the evaluation process is shaped as an iterative learning process including three steps: 1) collecting and documenting feedback on project implementation; 2) adopting “evaluative thinking” allowing to make sense of such feedback, and 3) developing a new understanding of situations to devise new measures addressing upcoming challenges (Kalpazidou Schmidt, & Bühler, 2020).

Three three-step evaluation cycles are organised throughout the project. Each cycle, lasting 4-6 months, includes:

- A two-month data collection phase (step 1)
- A monitoring meeting, involving the Local and the Central evaluation units, aimed at identifying critical issues and anticipating future bottlenecks or opportunities (step 2)
- Another two-month phase aimed at collecting information on the implementation of the CSI, especially for the critical issues identified in the monitoring meeting (steps 1 and 2)
- A larger monitoring session, involving the CSI team and relevant stakeholders, where the critical issues are reconsidered and, in case, new solutions are developed (step 3).

Starting from the second cycle, the collected information is also used for feeding the analysis at the cross-cutting level.

A set of templates (monitoring outlines, standardised minutes of each meeting, etc.) have been developed for each step. To collect first-hand information useful for the evaluation, interviews with stakeholders, policymakers, and other relevant actors are planned (15 interviews at least for each CSI during the second evaluation cycle). Moreover, specific items and topics are introduced in the tools already used in each CSI to get feedback, like workshops, living labs, focus groups, or community meetings.

The data processing is not confined to the end of the evaluation process. Rather, data are elaborated on during each evaluation cycle and interpreted in the three monitoring sessions. As for the analytical level, five Final Evaluation Workshops (one for each CSI) are planned where an overall assessment of the CSI will be co-developed by all the actors involved, based on a document jointly prepared by the Central and the Local evaluation units. As for the cross-cutting level, a preliminary document will be drafted by the Central Evaluation Unit and discussed with

all the CSI teams.

The results of the evaluation process will be presented in the Final Evaluation Report (based on the collection of data at the analytical level) and will provide the basis for the development of a Model of R&I socialisation through CS (based on the collection of data at the cross-cutting level).

CONCLUSIONS

As highlighted above, Step Change is intended to both favour the development of effective CSIs in three key societal areas (energy, health, and environment) and explore the potential of CS to favour the shift to a new social model of science characterised by greater openness to society. The evaluation approach has been therefore developed with the aim to assess the CSIs in connection with both of these objectives.

While there is a wide stock of knowledge on how CS projects can be assessed and supported via evaluation, this latter has been rarely used to better understand the possible systemic impacts of CS projects on, e.g., research practices, the structure of research organisations, the scientific teaching programmes, the research funding schemes, or the use of research as a means to address complex social and technical issues on the part of stakeholders. The risk is to consider CS as a niche approach, useful only for responding to specific needs, but which has little to do with the core structures, methods, and practices of research systems and organizations.

The lack of a consolidated experience in the use of evaluation to study CS projects also for its systemic impacts represents a serious limitation and makes the evaluation exercise carried out in Step Change particularly uncertain, especially for what concerns the identification of the key aspects to put under observation and the adoption of effective tools assess them (assessing long-term processes is always problematic). The approach is currently being tested and only one out of three planned evaluation rounds has been started (the last one is planned for the end of 2023). It is therefore too early to assess its effectiveness and value.

Although these limitations and risks, Step Change raises a question that deserves to be deepened, i.e., how to observe CS projects not only in their immediate or expected results but also for the possible longer-term change processes they are able to trigger both within science and in the way in which science is used in society.

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