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1. Executive Summary

Overview

Measuring societal impacts in Science, Technology, Engineering and Maths (STEM) research is important for STEM researchers and organisations as information on impacts is currently requested by project sponsors, research institutions and funding bodies to justify investment, research value, or secure bids. Typical impact measurements focus on quantitative indicators such as bibliometrics however it is argued that a more qualitative approach is needed to reflect societal impacts including wider social, cultural and environmental returns.

This investigation is driven by the requirements of a higher education institute and their need to develop strategies and implement tools that can be used to measure the societal impacts of STEM research projects.

The purpose of this study is to test and evaluate the use of Strategic Options Development Analysis (SODA) as an impact mapping tool and whether it is feasible and culturally desirable in the field of STEM research. SODA is most commonly used as a problem structuring tool, so this study contributes new knowledge to its application and use.

Method

Action research was used to explore current attitudes and practice of STEM researchers in a project setting. 9 participants took part in cognitive mapping interviews, qualitative surveys and focus groups. Participants were selected from 3 current STEM research projects within the same higher education institution.

SODA Individual cognitive maps were produced for each participant, these were then combined to create a causal map for each of the STEM research projects. A visual prompt was offered to all participants based on the Community Capitals Framework to provide structure and generate discussion ideas around potential societal impacts. Participants were surveyed on their attitudes to measuring societal impacts, previous experience, and feedback on their participation of cognitive mapping. This provided insights into the context in which SODA was applied.

Findings

Findings from the study regarding the desirability of using SODA as an impact tool, suggest that there may be some resistance to the measurement of societal impacts in STEM research and that this could affect the implementation of impact mapping tools into regular practice.
Survey responses from STEM researchers who participated indicate that measuring societal impacts is seen as important and advantageous not only for justifying funding and grants but also to communicate the value of their work. The main disadvantage identified was a concern that societal impacts would take precedence over research quality and place the focus away from research.

Findings as to the feasibility of SODA as an effective impact mapping tool indicate that all participants who took part in SODA cognitive mapping interviews produced detailed and rich maps. Mapping illustrated beliefs around potential societal impacts and demonstrated clear pathways and links between project activities and wider impacts. Combined causal maps were effective in showing multiple perspectives and creating an opportunity for emerging insights and dialogue between project members regarding societal impacts during the focus group feedback.

**Recommendations**

It is recommended that SODA be used as an impact mapping tool within STEM projects where there is scope and resource to do so. SODA involves producing both cognitive mapping and causal maps, typically produced using software for clarity. For this reason, projects with a short-time frame, limited resources or where STEM researchers’ availability is limited may not be suitable.

SODA requires an experienced facilitator with knowledge of SODA techniques to lead the interviews. A facilitator is also required for feedback sessions which are key to allowing participants space to reflect, explore multiple perspectives and gain new insight into the societal impacts that have been identified. Suitable training for facilitators should be considered to ensure SODA is properly implemented.

STEM research participants may have reservations regarding use of SODA and societal impact mapping, so sensitivity is recommended to encourage all participants to speak freely and contribute. For this reason, use of a visual as per the one used in this study is recommended to provide prompts where helpful.

**Conclusion**

In conclusion, SODA is an effective tool that can be successfully adapted for societal impact mapping. Investment in systems thinking approaches and training in SODA could provide a much-needed qualitative approach to impact measurements and capture the wider benefits of STEM research projects.
2. Introduction

The purpose and aim of this investigation is to explore current practice in measuring societal impacts in Science, Technology, Engineering and Mathematics (STEM) research projects so that recommendations can be made regarding the feasibility and effectiveness of using Strategic Options Development Analysis (SODA), a systems thinking tool, for ascertaining potential societal impacts within STEM research.

The objective is to understand whether it is feasible that SODA be applied and adapted as an impact mapping tool, to visually represent project team members perspectives and beliefs about societal impacts that may emerge from their STEM research project. The study will also explore whether it is culturally desirable for researchers to use this tool within the field of STEM.

In this study, the term ‘project’ is defined in line with the APM definition as a ‘unique transient endeavour to achieve planned objectives’. All projects participating in this investigation are run by researchers and project team members within the field of STEM.

This research is timely and important now as the measurement of societal impacts in STEM research has become more prevalent and requested by organisations, governments, and universities in recent years. Martin’s (2011) suggestion of publicly funded research becoming subject to ever more intensive accountability has remained true, due in part to increased levels of public money being invested in science. This is reflected in the requirement from project sponsors for project teams to provide key information on impacts at various stages of their research. There is also an increasing requirement for STEM researchers to justify their work by demonstrating the benefits of applying scientific knowledge to improve living standards and meeting basic human needs (Rull, 2014). This justification can be essential to gain grants or attract investment (Bornmann, 2012) or to meet research excellence requirements as outlined by the Research Excellence Framework (REF) who suggest impact should be measured in a quantifiable way, supported by appropriate indicators (HEFCE, 2011).

This research project is of importance to the higher education organisation it is situated in, as new strategies for impact measurement are being sought and implemented regularly. Investigating whether SODA could work as an effective impact mapping tool could add to current practice within the organisation and support STEM researchers throughout multiple stages of their research projects.

This research project is important to the field of STiP as it could contribute new knowledge to the area of soft systems approaches and the application of SODA as an impact mapping tool. It is also
important as including systems thinking in current project impact practices could encourage a more systemic approach to strategy and impact that does not rely on a business-as-usual approach. Meadows (2007) states ‘Continuing “business as usual” policies through the next few decades will not lead to a desirable future, or even to meeting basic human needs.’ and that it will only serve to widen the gap between the rich and the poor and exasperate environmental and resourcing problems and impair economic conditions for most people.

Contributing to the measurement of societal impacts in general is important as progress and growth through projects and human activity can produce unforeseen and unintended consequences on both the environment and division in standards of living. Finding ways to better identify and understand societal impacts can go some way towards mitigating this ‘profound influence on the global environment’ (Lewis et al, 2015).

3. Background

Literature suggests that typical impact measurements have been predominantly concerned with research excellence in STEM and limited to quantitative measurements such as bibliometrics (Sugimoto & Larivière 2020; Agarwal et al 2016; Chavda & Patel 2016), for example using journal impact factors (Garfield, 1999). It is suggested that a more qualitative judgement and holistic approach (Margherita et al 2022) is needed to measure the societal impacts of STEM research projects. Alkire (2010) argued that people value achievements that are not just economic and that develop over a long period of time including impacts on health, knowledge and livelihoods. This time frame can make societal impacts difficult to predict as impacts can ‘often take many years to become apparent’ (Rymer, 2011).

Science, Technology and Innovation (STI) policy has often measured quantitative indicators of research impact such as the early stages of commercialisation or technology transfer however Donovan (2007) implies this ignores wider benefits of intellectual, social, cultural and environmental returns. This study aims to address this gap in research by applying SODA as a specific tool to map wider qualitative impact data and presenting the findings.

When acknowledging the necessary but difficult task of measuring the social impact of research, Smith (2000) suggested that, whilst quality of research is an established way of measuring performance and potential impact, the ideal should be that all research be both ‘high quality and have considerable social impact’.

A difficulty identified by Bormann (2012) is a lack of consensus over defining and measuring societal impacts. A number of concepts have been introduced to try to clarify this, including Meulen and
Rip’s societal quality (2000), the idea of ‘usefulness’ (DEST 2005), knowledge transfer (Vaught and Ziegele 2011) and societal relevance (Holbrook 2013). These concepts go some way to producing agreement on what is considered a definition of societal impact however they do not offer a framework or qualitative method of measurement.

Literature on current tools and frameworks used in STEM research to identify emerging societal impacts of projects is limited and suggests a lack of impact tools used in practice. Smyth and Vanclay (2017) proposed that practitioners are using a range of bespoke tools or lists of themes that are not rigorous or put to review.

Participatory mapping tools such as ripple effect mapping and benefits mapping have been applied in project use for healthcare (Nobles 2022) and community growth (Sadeghzadeh et al 2022) but have not been applied to STEM research projects. Asset mapping is successfully used in impact measurement to provide a baseline in community development projects as ‘a method for unearthing and visually representing an individual’s or a community’s assets’ Greene et al (2013), however this measures the assets that currently exist and how they might change and therefore may not be suitable for identifying emerging societal impacts or predicting what they may be. Impact mapping via interviews has been implemented (Kirchherr et al, 2018), however specific impact mapping frameworks were not used to these support interviews.

Mapping tools produce participatory data however Frawley (2015) presents the argument that data shouldn’t be taken as a verifiable construct, proposing Duncan’s view (2005, cited in Frawley 2015, pg62) that it should ‘instead be viewed as a culturally and linguistically specific event’. Societal impacts may change with time and events and so a systems thinking approach that avoids seeing impacts as fixed may be beneficial. Systems concepts help to structure thinking and learning about the situation (Checkland, 1999) but do not imply a fixed outcome.

This project proposes to assess Strategic Options Development Analysis (SODA) as a tool to map emerging insights from participants concerning societal impacts of STEM project s. SODA, introduced by Eden (1977), has been used for over 30 years as a problem structuring tool within Systems Thinking in Practice (STiP). Abuabara & Paucar-Caceres (2020) describe SODA as a ‘participative methodology designed to provide dialogue, reflection and learning’. Measuring societal impacts is complex and subjective, especially as one person’s view on what is an improvement can vary from another. SODA uses the technique of cognitive mapping, using the language of the participants, to capture multiple perspectives on where potential impacts may emerge. It builds on constructivist philosophy (Kelly, 1955) and the idea that every individual has a unique and personal world view, that will be subsequently reflected in their view of the problem or situation (Mingers & Rosenhead,
2001). This could avoid a prescriptive gold standard of what should be measured in societal impacts and recognises the data as a ‘subjective picture rather than objective truth’ (Ackermann and Eden, 2020 pg. 147). This type of tool may also allow for an iterative approach as a STEM research project progresses.

Being able to consider the options and possibilities from various project activities not only enables participants to visualise possible impacts but also to make strategic choices about where the focus of a project should be to bring about the most desired impacts. Use of SODA may effectively influence participants to feel emotional commitment ‘to the outcomes, increasing their likelihood of implementation’ (Ackermann and Eden, 2020, pg. 141) This is particularly important for research projects as shared goals and aims are likely to lead to a more cohesive and successful project owing to a ‘shared vision’ (Christenson and Walker, 2004).

By illuminating interconnections, SODA may also reveal unknowns and unintended consequences research projects might produce. Smyth and Vanclay (2017) suggest that it is the large projects, often seen as solutions to problems, that will themselves be the source of considerable negative and positive social impacts. A systemic approach to impact mapping could lead to a less reductionist view of projects as merely a measure of economic success regardless of wider consequences. Ison (2017) proposes that without multiple perspectives and recognition of values and boundaries then the outcome could be the use of a systems approach that misses or even exacerbates significant social problems.

This research project is important to the organisation in which it is set as measuring societal impacts of research projects was established as a key organisational objective for 2022-2027. The current organisational strategy, Learn and Live (Open University, 2022) describes the need ‘To develop and embed ways to identify, track and evidence impact’ of research projects. When describing the societal challenges and impacts, the organisation stated that it was committed to focusing research around ‘three core pillars: sustainability, inequality and living well’ (Bandell, 2022) which can all be considered as societal impacts.

The proposed research project is important to the academic discipline of Systems Thinking as it applies SODA in an adapted and unique way, potentially opening up its use as an impact mapping tool. A modified SODA approach has been used to improve public participation in resource management (Hjortso, 2004) and as part of group model building for research with Aboriginal communities (Browne et al 2021) however it is difficult to establish whether SODA has been previously applied as an impact mapping tool and if so how effective it was, due to a lack of available literature. Including systems thinking approaches in the practice of STEM researchers and project
practitioners also encourages strategy based on reflection and a bigger picture view. ‘Rethinking agency goes from the ego to the eco, from the me to the we’ Klein et al (2021).

Research has shown a possible tension between STEM researchers and their attitudes towards the measurement of societal impacts in research projects and a ‘general dislike of impact considerations’ (Holbrook, 2011). This could potentially complicate any assessment of the effectiveness of SODA as an impact measuring tool, as resistance could mean that even an effective impact tool is not desirable for use by STEM researchers.

4. Project Evaluation and Specification
4i. Personal and Academic Suitability
The project is suitable for a student undertaking an MSc in Systems Thinking as it investigates the application of SODA as an impact mapping tool and uses participatory methods to generate new data and evaluate research findings. As an informed investigator working as a project manager within the field of STEM research projects, access to participants working directly in the field of relevant STEM projects could add value to current project management practices within the organisation. Systems thinking ideas and approaches have been explored previously during STiP MSc modules however this study enables a more in-depth exploration of the application of SODA and relevant ideas. It also builds on previous research skills developed during earlier modules particularly in synthesising research and conducting interviews.

The proposed project is suitable for relevant stakeholders as it is aligned with the organisation’s strategy and desire to create frameworks for measuring societal impacts in research projects. The development of an effective impact tool would improve practice and could provide valuable contributions towards bid proposals and justification of funding to wider stakeholders. It is possible that there may be some resistance if current theories and frameworks in use are challenged and existing paradigms questioned especially in project teams where best practice is favoured. This is demonstrated in Figure 1. It is important as an informed investigator to stay open to emerging insights and aware of current paradigms, ‘to realise that no paradigm is ‘true’ that everyone, including the one that sweetly shapes your own worldview, is a tremendously limited understanding’ (Wright & Meadows 2008, pg 16).
Figure 1 Stakeholder Mapping for T847
4ii. Project Feasibility

The ideas in this proposed project are relevant to the subject field of STiP as findings will bring new knowledge on the application of SODA, adapting its current use, and contributing to STiP capabilities and tools for bricolage. Bricolage, introduced by the anthropologist Claude Levi-Strauss encourages systems thinking practitioners to combine methods and materials to ‘create something new’ (Mambrol, 2016). The work planned would build on skills learnt during TB871, TB872 and T891 through enacting social learning and applying STiP techniques to societal impact decision making to ensure actions are culturally feasible and systemically desirable. Figure 2 is an adapted STiP heuristic demonstrating how using SODA enables people as change agents to engage with the situation in a systemic way.

This project aims to investigate current practices to measure societal impact in STEM research projects and to enact the use of SODA with participant groups to test its effectiveness so that recommendations can be made regarding the feasibility and usefulness of using SODA to draw out emerging and potential societal impacts within STEM research. Proposed outcomes are as per Table 1.
Table 1 Research Investigation proposed outcomes

<table>
<thead>
<tr>
<th>Personal Outcomes</th>
<th>As an informed investigator this project will enable new skills in:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Understanding existing frameworks and theories around impact evaluation and measurement in STEM research.</td>
</tr>
<tr>
<td></td>
<td>Evaluating the use of SODA as a tool that can not only show beliefs around emerging societal impacts but also be used to form appreciative learning and open dialogue around societal impacts</td>
</tr>
<tr>
<td></td>
<td>Developed skills in academic writing and as a STiP Practitioner</td>
</tr>
<tr>
<td>Primary Stakeholder Outcomes</td>
<td>By the completion of the project, stakeholders will be able to review feedback on the impact tool and implement chosen aspects of it in their own projects. This outcome will be achieved through focus group feedback and action research.</td>
</tr>
<tr>
<td>Outcomes for my Chosen Discipline</td>
<td>The successful completion of the project will allow for a systemic approach to impact evaluation and knowledge of the extent to which SODA can be applied to measure qualitative impact data.</td>
</tr>
</tbody>
</table>

Feasibility, schedule, scope and risks were assessed. Costs have been deemed as minimal due to fieldwork being carried out onsite at the organisation’s premises or remotely with no costs involved. Prior establishment of key relationships with STEM researchers provided access to resources and supported scheduling flexibility as there was provision from managers.

A schedule of work is provided in Figure 3
A risk report was carried out and key risks identified as high (coded red) are seen in Figure 4.

**Figure 3 Gantt Chart of proposed project schedule**

**Figure 4 Identified high level risks**
There were no ethical risks identified as high level. The organisation and stakeholders have not expressed a preference for a predetermined outcome or shown signs of professional political persuasions that could result in manipulation of design or exclusion of certain outcomes.

**Project title**

A systemic investigation into the feasibility and desirability of Strategic Options Development Analysis as a societal impact evaluation tool in STEM research projects.

**5. The Research Process**

**5i. Research Questions**

Inspiration for this research emerged through a need for STEM project teams to deliver information on societal impacts to project sponsors and organisations.

To ensure the research had appropriate scope, research questions were developed to frame the direction of the investigation. These questions were aligned with the aim of exploring current practice and experience in STEM research so that recommendations could be made regarding the feasibility and effectiveness of using SODA for ascertaining societal impacts of research projects. Research intended to generate new knowledge and was not designed to test a hypothesis or disprove current theory.

The following research questions were considered:

- Is it feasible and/or desirable to apply SODA to the area of STEM research?
- How open are STEM project members to using SODA as a tool?
  - How comfortable do they feel in doing so?
- Does SODA work effectively as a tool to draw out beliefs and insights into emerging societal impacts for these types of projects?

Benefits of framing the research in this way are that questions help to identify a ‘clear research topic’ (Silverman, 2017) and allow for priorities to be set. Framing research topics focuses the investigation not just on whether SODA could be effective as a tool for identifying societal impacts but also how appropriate its use is in this subject field. Exploring lived experience of STEM researchers and current practice allowed for understanding of the feasibility and desirability of implementing a tool such as SODA in this area.
Punch’s (1998) framework for workable research questions was adapted and applied to explore these research questions further (Figure 5).

Figure 5 Workable Research Questions adapted from Punch (1998)
Potential drawbacks of framing the research in this way could have arisen from lack of available data both in the form of secondary research on current practice and also willingness of participants to share their experiences. Attaching meaning to experiences of participants through qualitative approaches also raises methodological issues as to whether the researcher’s own assumptions are being applied to the narrative. For this reason, it is important to reflect on how data is being interpreted and as Krauss (2005, pg. 760) suggests, to acknowledge that the researcher is ‘a unique individual and that all research is essentially biased by each researcher’s individual perceptions.’

It is also critical to consider the language used in research questions and to consider variables such as what is understood as ‘effectiveness’ and what constitutes a practitioner being ‘comfortable’ in their use of SODA.

5ii. Model of Causality
The model of causality that informs this work is a realist/generative model of causality where the ‘nature of the outcome would depend on context’ (Open University, 2022a), modelled as C+M=O in Figure 6.

![Figure 6 Model of Causality](image)

The benefits of this choice are that it allows for context to be applied to the use of SODA. A linear approach that only considered the results SODA produced in identifying the societal impacts of STEM would not take into account the experience of the participants or the skills of the facilitator and how this may impact results. Context also allows for the participant’s definitions of societal impacts and their own value judgements to be included. Study of context and assumptions could provide useful scope for future research however it is not the focus of this current study. The
cognitive mapping of SODA is constructed using the natural language of the participants and therefore ‘becomes a model of the situation that is owned by those who define the problem’ (Ackerman and Eden, pg. 139). The outcome of the mechanism (SODA) can also be affected by group dynamics and individual personalities. For this reason, multiple projects allowed for deeper insights and reflect ‘different notions of causality’ (Bryman, 2016) in this setting.

5iii The Research Paradigm

There are two key research paradigms chosen as appropriate to this study. The first is a naturalist approach. This is congruent with the aim of this research project as from an ontological perspective, the findings will reflect the lived experience of participants. SODA cognitive mapping was used in participatory research and results are contextual ‘reflecting the subjective experience of each individual.’ (Open University, 2022b, para. 3). The epistemological approach to generating knowledge was undertaken as an emic enquiry in that the researcher interacted with participants and is not separate from that which they are seeking to investigate.

Due to the complex nature of identifying societal impacts, social learning is another paradigm relevant to the research methods of this inquiry. Participant worldviews and political and organisational context can influence values assigned to societal impacts. Social learning is ‘a potential paradigm for engaging with these broader institutional dilemmas’ (Woodhill 2002, pg. 57).

Social learning allowed for tensions to be debated and discourse around relevant reflexive modernisation to take place.

The focus of the approach was not to measure causal relationships but instead to generate theory so that recommendations can be made as to the effectiveness of the use of SODA in identifying societal impacts in STEM projects. Alternatives to this approach were considered. A positivist approach is less suitable as this investigation is not concerned with trying to prove or disprove a hypothesis. There were also variables in the projects and participants, so the data is not consistent with standard positivist testing methods. In the same way, interviews were open and semi-structured which is more in keeping with a naturalist approach as opposed to the closed questions reflective of positivism.

Within the naturalist approach, a combination of both interpretive and constructivist perspective was adopted. The values assigned to different societal impacts during the SODA mapping are explored by the researcher and participants, and contain a constructed narrative however the outcomes are still interpreted and ‘open to authentic representation’ (Open University 2022b, para.5). Elements of constructivist perspective are also in the generation of new knowledge and
emerging insights that are jointly explored by the researcher and participants during the focus group.

6. Research Approach and Methodology
Qualitative methods were chosen for this research project to explore ‘inner experiences of participants’ (Corben and Strauss, 2015). A qualitative approach allows for a less structured design that explores narratives and meaning. A qualitative approach also aligns with the naturalist paradigm that underpins this investigation.

The research is predominantly primary research in that interviews and surveys were conducted to generate new data. Exploration of STEM researchers’ lived experience of using SODA as a tool to help identify a project’s societal impacts was the main focus in line with the investigation aims. Some secondary research took place in the form of contextual research into current societal impact frameworks that can be utilised to offer a visual conversation prompt during SODA interviews.

This research investigation uses action research, which can be defined as a process of ‘systematic reflection, enquiry and action’ (Frost, 2002, pg. 25). This type of research can be carried out by individuals to inform their own professional practice. This research inquiry uses participatory action so that participants will actively be involved in the use of SODA through cognitive mapping but also able to reflect and inform their own practice through feedback in the focus group sessions and emerging insights from the SODA mapping.

The methodology is based on the cyclical four stages associated with action research and combined with Mertler & Charles’ (2005) suggested steps for the process of action research Figure 7.
Action research typically has several iterations as a cyclical process ‘guided by theory, which is applied to practice’ (Linde & Goede, 2023) informing future iterations of action and identifying changes that could be implemented. Due to the scope and constraints of this research investigation recommendations are made as to learning and future action, however further iterations were not enacted.

This method of research also allows for collective learning incorporating elements of an appreciative system. Focus groups to discuss the outcomes of SODA and the participant experience and practice created space for ‘the observation of the actual and comparison with the norm’ (Vickers, 1970) which contributes to informed action. It is the ‘exchange of ideas as a means of the participants gaining an appreciation’ (Gadamer, 2013) of the situation by listening and discussing other’s ideas about how they might go forward. This also goes someway to mitigating our own prejudgetion of a situation by including multiple perspectives.

Case studies were considered as an alternative method of research. Ismaeel cited in Crossman and Bordia (2021) noted that case studies can provide a depth and ‘richness of understanding’ that make this method suitable for a naturalist paradigm and qualitative approach. However it is the participation and collaborative learning through joint action and reflection not just observing participants that best informs the research aims and objectives and contributes to future practice in measuring societal impacts.
7. Data Collection and Generation Methods

Data was generated via STEM researchers, participating in SODA cognitive mapping interviews, a follow-up survey and focus groups.

Figure 8 shows the methods used for data collection.
Figure 8 Data Collection methods
Stratified sampling was intended for use to ensure a range of STEM projects were selected from a cross-section of STEM project types. Examples of types include space instrumentation, capacity building community projects and technology transfer. As there was scope for only 3 projects to participate, this selection is limited and further studies may benefit from including more project types. Random selection was considered, however the nature of the project type will have an impact on the types of societal impacts that might emerge and how effective SODA is in mapping these impacts. A cross-section of project teams allows for more data to be generated and for that data to be used to compare results and experiences where applicable.

Sample size was dependent on number of project team members and their availability. Minimum required sample size was three project teams with a minimum of 3 participants per project team. Sample size is reflective of the scope of the project and resources required to complete the data collection methods and subsequent analysis. A greater sample size is preferable to give a wider range of data and richness of information, this could be an area for future research.

Groups selection follows a range of population criteria which included:

- Participant must work within STEM research
- Participant must be actively involved within a STEM research project at the time of data collection

Data was generated in a semi-natural environment setting as participants were at their usual place of work, representative of STEM researchers. Information regarding perceptions, knowledge, attitudes and beliefs was collected in a short survey after the SODA interviews had taken place. Information regarding demographics; age, education, occupation was also collected at this stage. It should be noted that data collected regarding perceptions may more easily be taken out of context so care was taken not to alter participant language.

7i. SODA Interviews

Once participants had been selected, SODA cognitive mapping interviews were conducted with each project team member individually. This generated data aligned with the research question of the feasibility of SODA as a tool for ascertaining potential societal impacts within STEM research projects. Interviews were led by a facilitator. In this case the facilitator is the researcher conducting this inquiry.
During these individual interviews, principles of SODA were followed. Participants were asked to talk about both the project aims and activities, laddering up to goals where appropriate and laddering down to activities and options. Participants were encouraged to discuss the project in their own language and using their own perceptions and ideas about societal impacts. Wherever possible influence from the facilitator was kept to a minimum however a visual prompt was provided based on elements of the community capitals (Emery & Flora, 2006) Appendix A. Conversation statements were captured exactly as the participant had spoken and where required use of bipolar constructs gave clarity to statements.

SODA uses both cognitive mapping and causal mapping, the process of which is ‘aimed at helping a group or individual learn about the situation they face’ (Ackerman and Eden, Pg 139). In this research, SODA was used to draw out beliefs from participants about emerging potential societal impacts and what project actions and activities they felt would contribute to these impacts.

Once all individual cognitive mapping was complete, a combined causal map for each project was produced by the facilitator using drawing software.

In line with the aims of this study, research was designed to evaluate the effectiveness of SODA both in its ability as a tool to aid emerging insights regarding societal impacts and also in its desirability of use by STEM researchers. To provide further insights into the effectiveness of SODA, cluster analysis was undertaken by the facilitator prior to the focus group so that results could be discussed.

Desirability of use was explored through a qualitative survey and feedback during focus groups at the end of the study.

7ii Qualitative Survey
All participants were requested to complete a qualitative survey to reflect on their experience of using SODA to identify societal impacts. This survey took place directly after the SODA interview and before the combined causal maps had been presented to the group. The survey was designed to contribute to the research aims by seeking information regarding participants attitude towards societal impacts, feelings about using a tool such as SODA, and any previous experience in impact mapping. Due to the timeframe of the project, surveys took place before the focus groups so it is important to note that this could have influenced the experience of SODA that participants conveyed.

Due to a limited number of 9 survey respondents, it was possible to use open ended questions that allowed for participants to use descriptions, narratives and a ‘much wider range of adjectives’ (Sapsford, 2011). A potential drawback to this may be that respondents prefer to select a quick
numerical response rather than describing their own experience which could lead to a lack of information disclosed in the survey responses. The use of a survey also doesn’t provide the opportunity to follow up if a response is unclear. An example of the relevant survey topics can be found in Appendix B. Due to the small number of participants, confidentiality was prioritised and a sensitive approach taken when sharing insights.

A potential mitigation for lack of responses to open-ended questions is to use pre-coded questions to begin the topics. It was decided that the use of pre-coded questions to collect semi-quantitative data from the participants will be minimized as this would limit the options individuals had to express their feelings and emotional responses. To support the research aims an open qualitative survey was created allowing for open-ended responses and a narrative of the participant experience rather than predetermined categories. This was intended to avoid influencing the responses or restricting scope ‘Where answers are communicated using a predetermined set of categories, both questions and response categories will be in a researcher’s words’ Blaikie and Priest (2019 pg. 123).

It should be noted that even though the language used is that of the participants, observation of this data includes a level of interpretation so data should be considered to have an element of being constructed.

Survey results were analysed and then interpreted using thematic analysis. Visuals representation similar to the techniques used in Word Clouds were also created in some cases. This combined method was chosen to encourage inspiration learning (Kolb, 1984) and to enable methodological pluralism through ‘creative artistic expression as a means of developing understanding’ (Woodhill, 2002). Meditating on the words to allow for systemic awareness of the emotions involved creates space for emerging insights. This approach also encourages social learning through shared experience as the results can easily be discussed or shared as visuals.

7iii Focus Groups
Once all data had been collected and analysed, focus groups for each project took place, captured via audio and written up as a transcript. All participants from the SODA interviews were invited to attend with their project group and give verbal feedback on their experiences during the study. The causal map was shown and results of the SODA cluster analysis were provided. Discussions were fostered regarding the perceived effectiveness of SODA in identifying societal impacts. The use of a focus group provided the ‘opportunity to observe a large amount of interaction on a topic in a limited period of time’ (Morgan, 1997 pg.9). This method allowed for feedback from all attendees to be noted and considered when producing the concluding recommendations in line with the project aims.
Figure 9 is a revised schedule of the data collection/generation and analysis.
Figure 9 Revised data collection schedule
Including interviews, surveys and focus groups allows for a triangulation of the results regarding the effectiveness of using SODA to measure societal impacts in STEM projects. Using multiple qualitative methods generates new data and also builds on ‘data gathered through other qualitative methods’ (Morgan, 1997, Pg3).

8 Assessment of data collection

8i. Data Collection and Generation

During this research investigation, data was collected through a combination of surveys, interviews and focus groups as set out in Table 2

Table 2 Data collection and Generation

<table>
<thead>
<tr>
<th>Type</th>
<th>Date</th>
<th>No. of participants</th>
<th>Duration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SODA Cognitive Mapping (Individual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project A Space Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant 1A</td>
<td>13th Feb</td>
<td>1 and facilitator per mapping interview</td>
<td>1 hr allocated per interview</td>
<td>Participants were interviewed individually. All interviews were remote with the exception of Project A Participant 1 who attended in person.</td>
</tr>
<tr>
<td>Participant 2A</td>
<td>17th Feb</td>
<td></td>
<td>5 hours to redraw each cognitive map (x 9)</td>
<td>Cognitive maps were hand drawn by the facilitator during the interview</td>
</tr>
<tr>
<td>Participant 3A</td>
<td>17th Feb</td>
<td></td>
<td>1 day allocated to create combined causal &amp; analysis per project (x 3)</td>
<td></td>
</tr>
<tr>
<td>SODA Cognitive Mapping (Individual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project B Space Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant 1B</td>
<td>21st Feb</td>
<td>1 and facilitator per mapping interview</td>
<td>1 and facilitator per mapping interview</td>
<td>Interviews were recorded and transcribed using Microsoft Teams</td>
</tr>
<tr>
<td>Participant 2B</td>
<td>21st Feb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant 3B</td>
<td>21st Feb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SODA Cognitive Mapping (Individual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project C Food growing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant 1C</td>
<td>20th Feb</td>
<td>1 and facilitator Per mapping interview</td>
<td>1 and facilitator Per mapping interview</td>
<td></td>
</tr>
<tr>
<td>Participant 2C</td>
<td>20th Feb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant 3C</td>
<td>28th Feb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey</td>
<td>Responses between 20th – 28th February</td>
<td>9</td>
<td>9 Questions</td>
<td>Participants in the study were invited to complete the survey once their individual mapping interview had taken place. 100% response rate. Surveys were hosted using an online survey tool that participants could complete in their own time.</td>
</tr>
</tbody>
</table>
Data collection was impacted by industrial action which affected the availability of STEM research participants during the project. For the study to continue it was not possible to use stratified sampling as initially proposed. Convenience sampling was used to ensure that there were enough participants for the project to be viable. This impacted the project types available and resulted in the inclusion of two projects classed as space instrumentation (A+B) and one in community food growing (C). A wider cross section of projects may have provided opposing data on the use of SODA within STEM projects potentially affecting the generalisability of the findings. All participants met the criteria as STEM researchers currently engaged in research projects.

Reduced availability of participants also influenced interview and focus group scheduling resulting in concentrated time frames. This afforded participants less time to reflect on the process before feeding back to the focus group, which may have impacted the intended appreciative systems approach. It also impacted the preparation of cognitive and causal maps as there was limited time to make amendments prior to the focus groups.

The research study was successful in that the survey had a 100% response rate and respondents provided descriptive answers to the open-ended questions. This is a limited study in that there were only 9 participants however all participants engaged fully with the process, generating valuable data.

8ii. Tools and techniques used to analyse data

Data for this research project was prepared and sorted into the following groups:

- Survey results, Appendix C

- SODA Interview Mapping
  - 9 hand-drawn individual cognitive maps
  - 9 redrawn individual cognitive maps using Miro software
  - 3 causal maps drawn using Miro software
o Audio and transcripts for 9 mapping interviews

• Focus group Interviews
  o 3 audio recordings
  o 3 transcripts

All data was cleaned of errors and labelled so that projects could be identified without revealing personal data. Data has been catalogued to provide an audit trail to ensure transparency of the research undertaken.

Thematic analysis was used by adapting Braun & Clarke’s (2006) 6-step framework. Figure 10 shows the steps and the actions taken. Additionally visualisations through word clouds, and pie charts were used to examine survey responses. This framework was selected as it provided structure to the analysis that was also reflexive, allowing a ‘flexible interpretative approach to qualitative data analysis’ (Braun and Clark, 2012). Others analysis approaches were explored including content analysis and narrative analysis. Elements of content analysis were used when coding however frequency and meaning of words wasn’t the focus of this analysis. Narrative analysis was not suitable for this research project due to the type of data produced from cognitive mapping however it may be a useful approach for future further research into STEM researchers experiences and attitudes to impact mapping. Capturing narrative from STEM researchers as a ‘natural and appropriate means’ (Fina et al, 2015) to understand their experience.
To analyse transcripts and survey results the text was manually coded using a hybrid of both an inductive and deductive approach for qualitative data. Predetermined codes were used guided by the research aims and intentions that ‘pre-exist the analytic process.’ (Guest, Bunce, & Johnson, 2006) for example predetermined codes referring to limitations and perceptions of societal impacts. Further codes were captured as the data was analysed, allowing for insights to occur and a theme development process that was ‘organic, exploratory and inherently subjective’ (Braun and Clarke, 2016). Annotations were also made to connect themes and ideas Appendix D –
Data was examined and interpreted for repeated codes and emerging themes. An iterative approach was taken to complement the naturalistic research paradigm which predominantly includes qualitative data with multiple emerging themes and stages.

It was expected that data would be analysed by following a structure of preparation, analysis and interpretation, however this proved to be less linear in practice. The method of action research provided early insights, illuminating potential recurring themes such as participants feeling uncertain about their knowledge of societal impacts during first interviews. Early themes were noted in a journal and revisited.

Further analysis techniques include cluster analysis of the SODA causal maps to ‘reveal the emergent themes in the model’ (Ackerman and Eden, 2020, pg. 170) and to inform the research question of how effective SODA is in capturing perceived societal impacts of a STEM research project. Word cloud pictures were also produced to allow for reflection and insights into qualitative and descriptive survey responses. This word technique can ‘serve as a starting point for a deeper analysis’ (Heimerl et al, 2014). Graphics such as pie charts were also produced to semi-quantify the data.

9. Analysis and Findings
Findings have been presented in two sections, one addressing desirability and one addressing feasibility of SODA.

9 themes were developed from manually coding the qualitative data as seen in Table 2. These inform and explore the research questions through grouping data on participant attitudes, experiences and the use of SODA. Survey respondents remained anonymous so are quoted as such.

<table>
<thead>
<tr>
<th>THEME</th>
<th>Number of Mentions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant experience and comfort</td>
<td>16</td>
</tr>
<tr>
<td>Perceived importance of societal impacts</td>
<td>17</td>
</tr>
<tr>
<td>Advantages of measuring societal impacts</td>
<td>44</td>
</tr>
<tr>
<td>Disadvantages of measuring societal impacts</td>
<td>19</td>
</tr>
<tr>
<td>Limitations</td>
<td>15</td>
</tr>
<tr>
<td>Use of other tools</td>
<td>6</td>
</tr>
<tr>
<td>SODA useability</td>
<td>40</td>
</tr>
<tr>
<td>Facilitation</td>
<td>4</td>
</tr>
<tr>
<td>Emerging Insights</td>
<td>10</td>
</tr>
</tbody>
</table>
9i. Societal Impacts in STEM research (Desirability)

In this investigative study, data can be used to provide insight into the participant’s current perceptions of societal impacts. This is useful to understand the context and setting in which SODA is being applied and to identify whether there is a need or want for a systems thinking tool to identify potential societal impacts in STEM research projects.

Participants were asked to name three words associated with societal impacts. Figure 11 is a visual of the responses. The only word to be repeated is ‘people’ which is featured three times. All words could be interpreted positively, representing societal impacts as being beneficial and contributing to wellbeing and the environment.

Figure 11 Word association for societal impacts
9ii. Perceived importance

Question 3 of the research survey asked the respondent how important they feel identifying societal impacts is within STEM research. Of the 9 responses, two thirds said that it was either ‘crucial’ or ‘very important’. The remaining responses suggested the importance of identifying societal impacts was largely to assist in obtaining research funding. The survey responses were open ended, permitting respondents to write freely. A narrative emerged of a need to justify the research work being undertaken, not just to funding bodies but to the higher education organisations. During their focus group, Participant B1 (2023) acknowledged that information on societal impacts is something the ‘university increasingly wants’.

Although many of the respondents said they felt societal impacts were important, there were a range of views when it came to applying this to participants own research projects. Survey responses revealed perspectives as far ranging as it ‘Doesn’t seem relevant to day-to-day working life’ or ‘doesn’t cross my mind’ to ‘Research with no societal meaning is arguably pointless.’ Although this study is relatively small with just 9 participants, the varying perspectives can provide an insight into a potential disparity in whether researchers welcome the use of a tool such as SODA to measure societal impacts or whether they don’t see this as relevant to their project.

9iii. Perceived advantages

During the survey, respondents were asked to describe advantages and disadvantages of identifying societal impacts in STEM research. The answers were analysed using qualitative coding and combined with matching codes from the focus group feedback discussions across all projects. The question was not directly asked during the focus group, responses arose when reflecting on the societal impacts that had emerged through the mapping. Figure 12 shows the codes for advantages and their frequency.
Advantages of Identifying Societal Impacts

Figure 12 Proportion of responses, coded - advantages

The most prominent advantages referenced better communication of societal impacts and justification of funding. It could be argued that the advantages focus mostly around justifying the project’s value which in turn helps with project funding and further research bids. When asked how often project members were asked to justify their research, one reply from focus group participant B3 (2023) said ‘Almost all the time.’ Only a small number of advantages are linked to the theme of ensuring the project has a positive impact and mitigates negative impacts which could suggest that securing funding is a higher priority than understanding the societal impacts produced by a research project. This is supported by a statement made by focus group participant A1 (2023) that ‘there’s often a lot of pressure for quite immediate return on money spent not just on the longer strategic stuff.’

9iv Perceived Disadvantages

The perceived disadvantages of identifying societal impacts in STEM research projects centred mainly on tension between placing value on science and placing value on outputs, Figure 12. Over 76% of the responses coded as disadvantages suggested that there was a concern over emphasis being placed on outputs at the cost of the science and that a focus on identifying impacts would only drive this further. This may lead to a reluctance to engage with tools and practices that identify societal impacts, over concerns that a project may be undervalued if it cannot demonstrate how it will deliver positive impacts. This theme is further supported by survey responses suggesting ‘a
viable area of research might be stopped under the mistaken assumption that a failure to identify impacts at the time of assessment means that there are no impacts.’ A concern over placing value on impacts rather than science was also raised by a survey respondent who queried if tracking societal impacts at an individual project level could become ‘a time-consuming distraction from the research itself.’ These perceived disadvantages could affect how desirable it is to identify societal impacts for research projects in general and therefore how desirable the use of SODA would be for this purpose.

Data analysis found that few participants had used tools to map societal impacts previously with 3 of the 9 stating they had. Data also showed over half of survey respondents had worked in STEM research for over 10 years, suggesting that although seen as important, mapping and identifying societal impacts was not part of the practice of most STEM researchers. Figure 14 shows a visual of the phrases used by participants to describe their level of comfort when talking about societal impacts, descriptions range from ‘eager to talk’ to being ‘quite uncomfortable’. This may impact the desirability of using SODA, as survey responses showed participants repeatedly felt they ‘lacked the vocabulary’ to take part and were ‘Not used to engaging with societal impacts.’
9v. SODA as an effective tool for mapping Societal Impacts (feasibility)

The analysis and findings on feasibility contribute directly towards answering the research question proposed as to whether SODA will work effectively as a tool to draw out beliefs and insights into emerging societal impacts for these types of projects.

Analysis and findings include data for 3 different projects:

Project A – Space Instrumentation and development of new technology

Project B – Space Instrumentation and development of new technology

Project C – Community food growing shared through digital storytelling

All 9 participants provided interview information that resulted in complex cognitive maps. A selection is included in Appendix E – Cognitive maps demonstrated insights into the pathways and
links between activities, their outputs and how these contributed to overall aims for societal impacts. The maps were combined per project to produce causal maps, 1 for each project (Figure 15, Figure 16, Figure 17). Four of the community capitals (Flora et al, 2004) were added to the final causal maps as wider aims, as per the visual prompt used by participants.
Figure 15 Causal map for project A
Figure 16 Causal map for Project B
Figure 17 Causal Map for Project C
Participants had a range of previous experience with mapping societal impacts, however Project B was the only project where all participants had not participated in this or a similar activity before. Projects A and C had a small amount of benefit mapping experience however none had used SODA before. Despite this inexperience all participants produced interview content leading to a final rich causal map. Had there been more time between the cognitive mapping interviews and the focus group, further iterations would have been useful to ensure accuracy, clarity and placement of the nodes in all causal maps.

Participants from projects A and B expressed reservations about their ability to use impact mapping with SODA due to the nature and type of the project however differences were only apparent in participant attitudes and not in the richness of the mapping produced.

Use of SODA to map potential societal impacts of this project stimulated participants to consider how activities might contribute to wider aims and goals. In this way SODA was effective in mapping perceived impact pathways and their options and facilitating discussions that incorporated the multiple perspectives of the causal maps.

Figure 18 shows an example for each project of an identified pathway, connecting activities and options to wider societal impacts and aims.
Figure 18 Example Project pathways
Although this is an example for just one ladder per project, SODA mapping resulted in multiple pathways and options to reach wider impacts which encouraged discussion and understanding regarding the various strategies and activities that could result in societal impact. This discussion was particularly helpful in naming specific options where activities had been generalised.

For example, the activity of device building could potentially lead to outputs such as ‘creation of side projects’, ‘direct experiences’ and ‘Industrial collaborations.’ These in turn could lead to further options for skill development and job creation (Figure 19).

*Figure 19 Snapshot of cognitive map*
Cluster analysis was applied to each of the causal maps to examine identified themes and provide themes for focus group discussions. Cluster analysis was agreed by all groups to help illuminate possible impact themes and contributed significantly to the effectiveness of SODA.

Figure 20 shows a snapshot of two clusters for project C. The bottom cluster displays how a ‘shared understanding of community food growing’ could have multiple options for impacts including sharing best practice and waste reduction, eventually leading up to a high-level impact contributing to environmental capital. Positive feedback shared from Project C during the focus group was that ‘You could see a lot of connections going up there’ (Participant C2, 2023) and that the mapping was understood and ‘something that we can use in our project evaluation’ (Participant C3, 2023).
Figure 20 Cluster Analysis Project C
Figure 21 shows a cluster of impacts for Project B.

This cluster was used to discuss the higher-level impacts on social capital. The cluster illustrates how new networks and increased science opportunities have the potential to lead to societal impacts through the wider goals of impacts on standards of living and opportunities for all. The cluster highlights a strategic option of ‘an alternative to traditional academic routes’ with potential pathways to achieve this. The participating project lead commented that this was the ethos of the project and rarely acknowledged when discussing impacts. This could suggest that SODA was effective in drawing out beliefs around impacts that may typically be overshadowed and contributed to defining the purpose and shared vision of the project.

Findings of focus group transcript coding suggested a shared agreement that SODA had revealed insights that would not have emerged without this tool, in particular through seeing the combined causal maps and discussing them.
Participant insights emerged after seeing contributions from other participants with different perspectives on the same project map. An example of this is Focus Group A where a potential significant impact around combining technology aims with space exploration aims emerged.

An excerpt from the transcript shows dialogue between participant and facilitator:

*Participant A1: This is bringing together science and technology.*

*Participant A1: It's a really nice example of that collaboration, which I think gets overlooked a bit too much because people look too far for stuff and actually this is something very close to home*

*Facilitator: Do you think mapping has resulted seeing it in a new way?*

*Participant A1: Yes, for sure.*

*Participant A1: I literally, I hadn't thought of it until we were seeing that there.*

Many emerging insights also came from being able to see where expected impacts were missing or not sufficiently represented. An example of this was Focus Group B who having discussed the causal map, identified that they were not contributing towards education for students and that the mapping ‘highlights we haven’t managed to do that’ (Participant B3, 2023).

Analysis of codes assigned to usefulness, that emerged across all 3 focus groups, highlighted that being able to visualise pathways was the most useful aspect of SODA. Participant B1 (2023) reported that they could ‘use this to plot a path toward that’ when referring to linking activities to aims. Focus group A provided feedback that SODA could be useful for demonstrating the end benefits, and ‘demonstrating the links and pathways that get there’ (Participant A2, 2023), maximising pathways to impact. Visualisation of pathways was also deemed useful to see patterns and linkages. Participant C3 (2023) remarked ‘as you build things up, moving up from options to strategic directions, then you see patterns of where they’re linking’. In a similar way being able to view a more holistic picture of the project was found to be useful by all three focus groups in that it ‘gives you a feel for the scale of one aspect’s contribution to the overall picture’ (Participant A1, 2023).

9viii. SODA Limitations

Findings suggest that participants may exhibit reservations around aspects of using SODA to map societal impacts in STEM research projects. Themes that emerged across all groups highlighted that the complexity of the mapping at project level could be overwhelming and difficult to distil down. It
also suggested that a reductionist view might be taken. Phrases repeatedly found in the coding were ‘needs some streamlining’, ‘needs to become smaller’ and to ‘only show 1 pathway at a time’. All focus groups took place remotely due to scheduling restrictions, so mapping was displayed on a shared screen during the focus groups. Following feedback from Focus Group A, subsequent groups were sent causal maps in advance to be viewed individually. Data showed references to the map being overly complex in groups B and C were half that found in A.

Questions were also raised during feedback as to the role of the facilitator and ‘how you’ve put these words in the places you have’ (Participant B3, 2023) relating to the influence facilitators have as to the placement of arrows and linkages. Acknowledgement of the influence of the facilitator on mapping should made known. Follow up focus groups and further iterations are crucial in producing a causal map that can be agreed upon by all participants.

10. Conclusion
The aim of this study is to explore current practice in STEM research and use SODA to map beliefs around potential societal impacts of STEM research projects, so that recommendations can be made regarding the feasibility and effectiveness of using SODA for this purpose.

Findings indicate that the theoretical tension between science and societal impacts as suggested by the literature review was evident in the STEM research projects surveyed and should be considered when engaging participants in SODA. An understanding that ‘the societal impact of research is not always going to be desirable or positive’ (Bornmann, 2012) could ensure that facilitation is approached in a way that does not increase tensions and encourages academics to pursue research that delivers both scientific and societal impact as put forward by Llopis et al (2022). Findings also indicate that STEM researchers feel they lack the understanding and vocabulary needed to participate in mapping societal impacts which may present a barrier to the acceptance of SODA and it’s feasibility in STEM.

Participant responses to the survey regarding advantages and disadvantages supports the literature review findings that there is recognised pressure from funding bodies to provide justification for project funding and to show the value of the research through impacts. Analysis of survey responses indicated a consensus that identifying societal impacts contributes to better communication of the value of the work of STEM researchers not only to funding bodies but to the general public.

Conclusion on the desirability of the use of SODA in impact mapping of STEM research from the findings suggests that there are multiple attitudes both in favour of and reluctance to evaluate
societal impacts of STEM projects using SODA. It is recommended that the facilitation of SODA interviews and follow up communication is adapted accordingly.

SODA was effective and feasible as a tool to demonstrate pathways that link activities and their potential impacts. Findings support the idea that it generates ‘context through chains of action-oriented argumentation’ (Ackermann & Eden, 2010 pg 149). Mapping reflected participants beliefs about where impacts could be created, and the final causal map provided a basis for discussions about how viable these impacts were and how best they could be achieved. In this way SODA proved effective in facilitating strategic options discussions. The approach to using SODA was modified in that participants spoke initially of fixed project activities rather than suggesting multiple options for actions. These activities were revisited during the focus group where options were subsequently discussed. The approach also returns to a one-to one focus on individual mapping which has commonly been replaced in SODA methods by group mapping to save on time and resources. This proved to be key in establishing emerging insights from other perspectives that may have been overlooked had there only been group mapping and allowed the focus groups to facilitate SODA as a ‘negotiating device’ of strategy reflection and development (Abuabara and Paucar-Caceres 2021, pg 1063).

Although this was a study of only 9 participants, research suggests that SODA can be applied not just as a problem structuring method but also succeeds as a tool for impact mapping especially in proposing and framing shared project aims and intended impacts of STEM research projects. In this way it could expose the potential for Systems Thinking to be incorporated into the practice of project teams who had not previously used these tools and methods. Survey results supported the findings of the literature review that systems thinking tools and impact mapping tools are not commonly part of project practice in STEM research.

Initial findings suggest SODA could be an effective tool in appreciative systems theory enabling participants to ‘exchange ideas’ (Godammer, 2004) and gain an appreciation of the situation as a whole, reflecting on and informing their own practice. Participant C1 (2023) noted that use of SODA can ‘feed into our self-reflection.’ allowing their own practice and ethos to be examined and reflected upon.
Initial recommendations are that SODA could be a useful tool for STEM projects to encourage researchers to think holistically about societal impacts and to incorporate a systems thinking approach to their research impact aims. This should be explored further by the organisation and all project teams involved have requested to further explore this practice. There was a shared understanding that pathways suggested by the maps are not fixed and can change over time so should be revisited and reiterated.

Further studies are required to establish whether SODA could be implemented successfully in STEM research projects in other higher education institutions. In some cases this may require additional resources as a facilitator proficient in SODA is required so may not be viable without additional training.

It is recommended that time constraints and project scope are considered when implementing SODA at project level as this may be viewed as a lengthy process when there are already project time constraints. For this reason SODA may be more feasible when used with projects with a longer time-frame and sufficient resources.
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Appendices

Appendix A

Visual Prompt for Cognitive Mapping
Appendix B
Example survey topics

Appendix C
Survey Responses

Q1. What 3 words would you most associate with Societal Impacts?
   People, bottom up, resistance
   People, benefits, contribution
   people, environment, culture
   wider benefits elsewhere
   N/A
   Qualitative, Necessary, Diverse
justice, sustainability, equity
generative unexpected crucial
Economy, knowledge, wellbeing

Q2. Please describe how comfortable you feel discussing the societal impacts of a project you are currently working on?

enough comfortable

Very comfortable, it is something we need to consider in our general work now, when applying for funding and when proposing research. Sometimes it is difficult to see the societal impact though.

medium

eager to talk but feel I lack the vocabulary

Quite uncomfortable prior to the event as I was not sure of what would be expected. More comfortable during the discussion but still not entirely sure of what to say or how to phrase the responses.

Not uncomfortable, but certainly not as comfortable as when talking about the scientific impacts. I don't think I could talk for as long, or as coherently, about societal impacts as society isn't usually something that crosses my mind or seems at all relevant in day-to-day working life.

Very happy to share experiences

Depends very much on the project and how much I feel like the project is aligned with my values and our overall ethics in the project team. Even if or perhaps especially when things are not going great it feels really important to talk about them.

Quite comfortable

Q3. Please describe how important you think it is to identify societal impacts within STEM research and why?

Very important

We use public funds, so we need to tease out how our research feeds back into the society that pays for it, and then communicate that effectively.

it's important for planning so that positive impacts are encouraged and negative ones prevented or reduced
I think it is very important that STEM research engages with society and that impacts are promoted and communicated in both directions. I also recognise that not everyone is going to be naturally pre-disposed to engaging with these endeavours - and that is also fine.

I think it is very important. Ultimately impacts are how research is justified to funding bodies, government, and the public. Research with no societal meaning is arguably pointless, or at least can be perceived as such. However, it is important to note that impacts may be present in a way that is not immediately obvious.

It's only important to me personally in as far as the various funding bodies increasingly require this to be done. I can understand the argument that public money being spent should result in outcomes for the public good, but I see societal impacts as very much secondary to the scientific goals of the research in question. Science for science's sake ('blue-sky' research) can often go unfunded or gets devalued because of the preoccupation with things which provide tangible outputs for the public in the short term.

Ultimately, the purpose of research, including that conducted in STEM, is to make life more sustainable and equitable, so assessing the societal and ecological impact of our research is crucial.

I think it is absolutely crucial as I think we need much more co-designed research and ways of making that happen.

Very important because what we do needs constant and up-to-date justification

Q4. Please describe any advantages or disadvantages you think may arise from identifying potential societal impacts in STEM research projects?

Advantage: learn from sick points/mistakes. Disadvantage: some project contradictions might arise that are not easy to be solved.

A big disadvantage is that too much focus on societal impacts could potentially adversely bias the projects that are funded and proposed. Blue skies research should have the same perceived value as direct-impact research, as blue sky research often produces societal value later on.

Advantages: can steer project towards more positive impacts. I can't see any disadvantages.

"Advantages

- makes us think outside our bubble, and maybe even see how we might be perceived from the outside
- enables us to communicate the value of what we do (in maybe help justify the costs)

Disadvantages

- risk of being perceived as part of the latest fad"
"Advantages would include an understanding of how research can be disseminated in a way that makes sense to people who are not intimately involved with it. It also allows future pathways to be identified for further research, commercialisation, or technology transfer and allows dead ends to be identified more easily.

The main disadvantage would come from situations where there is no obvious societal impact. In these cases it is possible that a viable area of research might be stopped under the mistaken assumption that a failure to identify impacts at the time of assessment means that there are no impacts."

Advantages could include developing new, unexpected collaborations, or opening up new potential funding streams from sources other than the usual bodies and agencies. Explaining any impacts to wider society to the public might also help raise support for increased government spending in STEM. Disadvantages could be that it becomes a 'tail wagging the dog' scenario, where legitimate project spin-outs become seen increasingly as the main objective of research funding, or trying to justify or track any societal impacts at an individual project level becomes a time-consuming distraction from the research itself.

An advantage is that we can use impact evidence to better promote STEM research in the public domain, as this is the most straightforward way to engage a non-societal audience. The disadvantage is that not all impact can be measured and impacts can emerge slowly/transversally. So research that is crucial which will ultimately deliver profound long-term impact might be overlooked for simpler projects that deliver immediate simplistic impacts e.g. developing some gadget/instrument which can be sold commercially (but doesn't really transform people's lives).

"Advantages: highlights their importance and that they should be fundamental, helps to mainstream asking for and assessing them

The only disadvantage I can think of if it somehow exposes vulnerable people in the process"

Knowing the potential societal impacts could improve the quality of our grant applications. On the other hand, paying too much attention is a distraction from doing science and can have negative impact on our abilities to do competitive research.

Q5. Have you previously used any tools or techniques to map societal impacts within a STEM research project? (0 is no, 1 is yes)

0,1,0,0,0,1,1,0

Q6. If you answered yes to the previous question, please state what tools and techniques were used.....

A community capitals framework, and also input-output financial modelling

N/A

Ripple Effect Mapping, Participatory Video
Ripple Effect Mapping Workshop

Q7. What’s your age range?

Q8. What’s your current employment status?
Self-employed X 1
Employed full-time x 8

Q9. What’s the highest level of education you’ve completed?
Masters / Graduate Degree x 2
Doctorate x 7

Q10 How long have you worked in STEM?
1-5 years x 1
5-10 years x 1
10+ years x 7
Appendix D – Example Annotations

At an more, more practically LED rather than.
0:6:19.800 - 0:6:20.730
End goal lead.
0:6:24.840 - 0:6:25.380
OK.
0:6:26.150 - 0:6:32.300
So. So what I kind of hear there, I guess is that by being exposed to different communities with different ways of doing things.
0:6:33.310 - 0:6:34.990
We get a new perspective on.
0:6:35.740 - 0:6:38.380
We get a new perspective on what we do.
0:6:39.500 - 0:6:39.310
Umm.
Appendix E –
Examples of Cognitive Maps (Projects A, B & C)