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A Meta-Synthesis of Ethics-Aware Software Engineering Practice: A Preliminary Framework

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Abstract. The use of evidence-based practice to inform ethical software development is important for all stakeholders to achieve successful software and address the ethical needs of those affected by it. Although research exists on various mechanisms for supporting ethical software development, their integration into a framework that enables expansive ethics awareness and adherence is lacking. This study fills this gap by conducting a qualitative metasynthesis of studies that implemented and evaluated mechanisms to support ethics in software development. Meta-ethnography methodology was followed and supported by the PRISMA reporting guidelines to achieve the study's objective. Most of the mechanisms identified in the four selected studies are oriented toward supporting the integration of ethics into software development in the artificial intelligence domain, rather than the broader software engineering ethics spectrum. The study contributes a conceptual framework for ethics-aware software engineering practice. The proposed framework requires empirical validation. In addition, Further studies are required to explore other resources reporting on other transformative technologies to expand the framework for improving the software engineering practice.

Keywords: Ethics-aware software engineering, Software engineering ethics, Qualitative meta-synthesis, Meta-ethnography, framework development

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1. INTRODUCTION

Software engineering, from its inception, has been characterised by what is termed the software crisis, the labelling of the myriad failures of software and its subsequent negative consequences. Ethical lapses have been identified as a major cause of software failures, negatively impacting society and businesses [1]. To mitigate the negative consequences of ethical failures, beyond existing interventions, ethics-aware software engineering (EASE) practice has been identified as important for supporting ethical software development [2]. Ethics-aware software engineering encompasses practices that consider stakeholders' ethical needs and apply ethical principles to ensure the software product does not pose ethical challenges [3], [4]. This is important because of the increased interest and the need to improve attention to the ethical dimensions in the development of software systems [5]. Doing so will ensure that potential causes of software ethical failures are identified early and addressed promptly.

Software engineering practice generally provides a framework to facilitate the various activities of software development. These include activities encompassing the technical and social aspects of software development. Whilst there exists significant effort in improving the technical aspect of software development, the practice tends to overlook the social aspect of it, especially those dealing with ethics [6]. The ethical aspects, which concern the social, deserve equal attention alongside the technical. The overemphasis on technical aspects and the ignorance of ethical aspects of software development will lead to decisions and, subsequently, to software lacking an ethical perspective. Therefore, a good software engineering decision demands a balanced consideration of both the technical and ethical dimensions of the decision [7]. Hence, raising ethical awareness in software engineering across the software process is important [8]. Particularly due to ethical challenges emanating from emergent technologies such as artificial intelligence [9].

To achieve ethical software development, organisations need to ensure that software ethics is part of organisational objectives [10]. Therefore, employees will be aware that all software endeavours must reflect ethical principles to achieve organisational objectives [3], [11]. Different types of research studies present various mechanisms for

ethical software development, including ethical guidelines and principles as well as tools used for decision-making and deliberation [12], [13], [14].

The need for ethics awareness in software engineering dates to the realisation of the social implications of computing. Hence, a good software engineering decision demands a balanced consideration of both the technical and ethical dimensions of the decision [7]. According to Bricknell and Cohen [15] ethics awareness involves knowing the applicable ethics codes in the work environment and using them for guidance when confronted with a moral problem. situation requiring ethical. The use of codes of ethics in software development has proved useful in addressing ethical challenges. To heighten the ethics awareness, software engineering as a field has undergone a process of improvement to shape it into a professional practice [16]. The improvements include the formulation of professional ethics containing guidelines to train and support software practitioners [7]. This is supplemented by the establishment of professional bodies to guide the practice and hold members of the profession accountable for their ethical responsibility [17]. In addition, research contributed various frameworks (such as those for decision-making, ethical deliberations, etc.) to assist with ethical considerations in the software process [12], [13], [14]. These efforts signify the importance of practice-wide or professional drive towards ethical awareness in software engineering.

Several studies have examined ethical awareness to determine its impact on the outcomes of software development initiatives. The studies analysed gender, age, ethical leadership, perceived importance, ethical responsibilities and obligations in relation to ethical behaviour [18], [19], [20], [21], [22]. For example, a study by [23] which probed practitioners at the managerial level shows that ethical awareness enhances ethical sensitivity, facilitates the easy identification of ethical issues, and provides confidence in handling ethical dilemmas. However, [11], [13]indicates that although ethical awareness is useful for detecting ethical issues that might impede software development outcomes, suitable environments and tools are needed to support ethical practices throughout the software process.

To ensure that awareness extends beyond mere knowledge of ethical principles and that conducive environments prevail for successful ethical software development, [2] suggests an ethics-aware software engineering practice. Ethics-aware software

engineering practice is the practice of explicitly accounting for ethical issues by ensuring they are integral to risk evaluation in the software life cycle [24]. Furthermore, [4] states that for this ethical practice to succeed, organisations should embark on a deliberate mission to improve organisational practices, codes of conduct and development of frameworks for software and business process improvement. In addition, research endeavours should provide evidence-based, synthesised support to inform the software engineering practice. Although the use of qualitative synthesis has not been extensively explored in software engineering, it can significantly influence practice [25].

Metasynthesis is considered an "*umbrella term referring to the synthesis of findings across multiple qualitative reports to create a new interpretation*" [11]. It mainly provides enquiry tools with the specific purpose of identifying primary qualitative studies and applying specific methods to interpret and integrate their findings to provide a holistic interpretation of a phenomenon [27], [28]. The outcome of this accumulated knowledge is used either to develop a new theory, an overarching narrative or a wider generalisation [27] in order to improve the practice [28]. With this broadened understanding, the integrated view becomes more powerful than the isolated results of individual investigations in qualitative studies [26]. Hence, the application of metasynthesis has yielded notable results in various research fields.

Metasynthesis is widely used across fields such as health practice and the social sciences to support evidence-based practice [29]. Although the use of qualitative synthesis is relatively new in software engineering, it can also benefit the practice as part of evidence-based software engineering [25]. The evidence-based software engineering primarily serves to provide the best possible integrated current best research evidence derived from practical experience and human values to inform improved choices in the development of software [30]. Therefore, this approach is well-suited for organising inputs to inform the development of improved ways to support ethics in software development. In conducting a qualitative meta-synthesis for the interpretive analysis of qualitative studies, phenomenology, ethnography, grounded theory, and case study methods can be adopted [28].

Notable research studies which applied meta-synthesis in the field of information and communication technology (ICT) include those conducted by [31], [32] and [33]. The study by [33], specifically applied meta-ethnography to interpret and translate qualitative studies on solo software development methodologies (SSDMs) to develop a framework for supporting freelance or solo software developers' efforts to achieve quality software. Although applying ethics in software development leads to higher-quality software [34], the study by [33] focused on developing a framework to support solo developers in creating high-quality software. The study by [32] analysed and synthesised studies using the metasynthesis method to develop a comprehensive, stepwise framework to assist managers in mitigating risks associated with migration to cloud computing. [31] conducted a study to synthesise qualitative studies on the use of computerised clinical decision-support systems (CDSS) on how they support decision-making in healthcare. The study identified the reasons and causes of difficulties in integrating CDSS into clinical work. Although the three studies cited above were conducted successfully, they did not address the frameworks for ethical awareness and adherence in software development.

The lack of synthesised qualitative studies in software engineering, especially those focusing on ethical software development to support evidence-based software engineering, is a concern [26]. This leaves the field to remain dominated by individual studies focused on developing supporting mechanisms for software engineering ethics. Furthermore, in terms of evidence-based support, the field still lacks the means to translate existing mechanisms into viable, accessible practices usable across the various domains of software development [11], such as framework interventions [2], [10]. Achieving adequate ethical awareness among stakeholders remains a challenge [9], mainly because ethics in computing evolves with dynamic stakeholder perspectives and emerging technologies [35]. Therefore, there is a constant need to develop updated frameworks grounded in evidence, drawing on studies that have developed supporting mechanisms for software engineering ethics, incorporating current stakeholder perspectives. Findings from these studies have not been synthesised to determine how they can, in a broader sense, support ethical software development. To make a scholarly contribution to filling this gap, this study aims to apply qualitative metasynthesis of prior studies to identify components and integrate them into a conceptual framework for ethics-aware software engineering practice, thereby expanding its practice rather than leaving it informed by

individual studies. To accomplish the said objective, the next research questions are devised to guide the study:

RQ1: What are the components of the existing mechanisms used for ethics-awareness and adherence in software development?

RQ2: How can the components be integrated into a framework for ethics-aware software engineering practice?

This study is organised as follows: methods in section 2, results and discussion in section 3, and conclusion in section 4.

2. METHODS

The approach in this study is to systematically identify and synthesise appropriate qualitative studies offering solutions or mechanisms for ethics-aware software engineering practice. The goal is to derive components and reorganise them to inform the development of an updated framework for ethics-aware software engineering practice. To achieve the goal, a qualitative meta-synthesis that provides a novel, integrative, and comprehensive interpretation of individual studies' findings, with a better understanding [26], [35] is followed. Furthermore, the study adopts theoretical development in meta-synthesis [28] to conclude with a thickly described product constituted by components identified from individual studies, as guided by [28] to o guide practice based on evidence [36], [37].

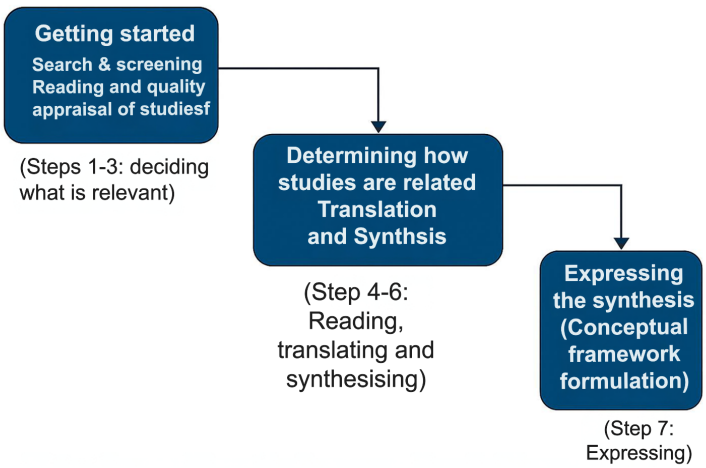

Figure 1: Meta-ethnographic research workflow for the study

To achieve the study's results, the seven steps of meta-ethnography [38] are applied and supported by reporting guidelines [39]. The process is depicted in Figure 1 and described in detail from step 1 to step 7 to guide the development of the proposed framework. In addition, the study adopted the PRISMA framework for reporting reviews [40].

3.1 Getting started

To complete the first step, we formulated the problem in the paper's introductory section. The need for synthesised evidence to improve ethics awareness and adherence in software development provided the rationale for this study. In addition, this synthesis is more needed to develop a conceptual preliminary framework to support ethics-aware software engineering practice and inform future research.

3.2 Search and selection of applicable studies

The search strategy was developed to locate suitable studies from IEEE, SCOPUS, Web of Science, and ScienceDirect. These databases were chosen because they are among the most frequently used by researchers [41] in the computing field [42]. An automatic search was conducted by running the search strings against the identified databases for articles published from 1990. The article search, selection process, including screening and quality review, is depicted in the flow diagram in Figure 2. This is useful for transparently demonstrating the selection of materials to develop the proposed framework. The flow diagram was generated using a PRISMA 2020-compliant tool [43].

A total of 11207 articles were retrieved by the search strings, which included "software*" and "ethic* and (framework or model" and "method*)". After deduplication of 1354 duplicates, 9853 articles remained and were further screened for titles and abstracts to determine their suitability for the study according to the criteria in Table 1. The criteria were established to ensure that only materials suitable for developing the framework are selected, and the selection is justified. The articles considered are empirical journal and conference papers written in English, identified from the selected databases, matching the search strings, and with abstracts and publication dates from 1990. The title and abstract screening yielded 53 empirical studies meeting the inclusion criteria for full-text review.

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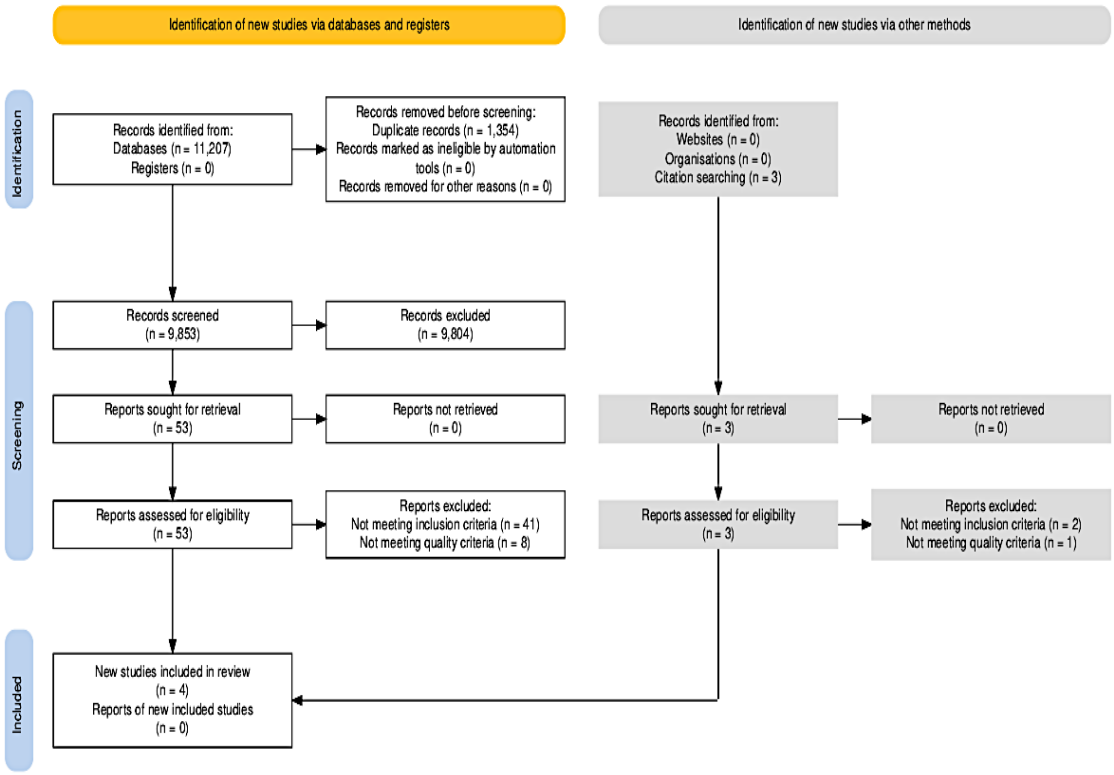

Figure 2. PRISMA flow diagram

Full-text screening of these fifty-three articles ensured that studies focused on the development and evaluation of solutions or mechanisms for ethics awareness and adherence were included. The full-text screening of the studies yielded twelve articles. These were supplemented by articles identified through citations, which were also screened by title and abstract, yielding three additional articles. This led to 15 articles being presented for quality assessment.

Table 1. Inclusion and Exclusion criteria

Item	Inclusion	Exclusion
Publication Type	journals, conference proceedings, and book chapters	Grey literature
Disciplines	Studies from the disciplines of information systems, software engineering, and computer science are considered	Not from the mentioned fields
Text availability	Full text can be found	Full text cannot be found.

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Item	Inclusion	Exclusion
Language	English	Articles not written in English
Time frame	From 1990 to 2025	Articles before 1990
Type and content	Empirical studies involving the development and evaluation of mechanisms for ethics awareness and adherence in software development	Articles that do not address the development of a mechanism for ethical awareness adherence in software development.

The quality assessment evaluated the remaining 15 articles for relevance and methodological quality, in accordance with the criteria outlined in Table 2, to ensure that the study used high-quality materials. These assessment measures were established to ensure that the proposed framework is derived through the synthesis of quality materials. These included assessing the objectives, methods and findings of the studies to determine whether they were clearly defined and aligned. The quality assessment items were allocated a score of 1 if the review result was Yes, 0 if the review result was No, and 0.5 if the review result was Partial. This assessment was applied across all studies, regardless of mechanism type or domain specificity within the software engineering spectrum. This led to only four articles meeting the quality assessment criteria, all of which fully satisfied the criteria by scoring 1 on all items. Moreover, the included articles specifically present a proposed, developed and evaluated mechanism for ethics awareness and adherence in software development.

Table 2. Quality Assessment Criteria for the study

Item Assessment
1) Q1. Study type. Is the study empirical?
2) Q2. Is the study aimed at developing a mechanism for ethical adherence in software development?
3) Q3. Does the study implement and empirically evaluate the proposed mechanism?
4) Q4. Are the purpose/objectives of the study clearly stated?
5) Q5. Is the research method clearly defined (data collection and analysis)?

Item Assessment
6) Q6. Is there a clear link between data analysis and the study findings that lead to a sound conclusion?
7) Q7. How credible are the findings?

3.3 Reading and re-reading of the studies

The four articles, comprising two journals and two conference papers, that survived the screening and quality review deemed suitable for further analysis and synthesis were reread. This was to ensure a full understanding of their content and to be acquainted with the key concepts to inform the data extraction [44] and the synthesis process [45]. Data extraction and analysis were conducted by one of the reviewers to answer the study's research questions, which are stated in Section 1. However, to ensure transparency and that consensus is attained [46], the other reviewer verified the completeness of the work. Table 3 provides characteristics of the included studies, including publication type, publication year, research methodological aspects and other data on the aspects of interest extracted from the article regarding the mechanisms for ethics-aware software engineering and main concepts.

3.4 Determining relationships among the studies

To determine how the studies were related, we aligned with the guidelines provided by [39], [47]. There are several suggested strategies for determining how the studies relate to one another, such as themes and metaphors. For example, as [47] suggests, we have listed the concepts from each study in Table 3 towards developing the proposed framework. These are useful for juxtaposing and establishing relationships among the studies. This was possible to achieve as outlined in Table 3, given that the remaining studies' focus was clear and shared common concepts. Building on the details in the table, we have summarised the concepts and their constituent elements in a diagram in Figure 3 as recommended by [47] for the synthesis of limited studies. This approach helped to structure the framework. The commonality amongst the studies is that they focused on mechanisms as interventions to raise ethical awareness and support adherence in software development. Each study provided a solution for ethics in a particular software domain; it evaluated the solution and analysed its use. In addition, the framing of each study is based on ethical values and principles and involves software stakeholders.

However, the domains in which the studies provided solutions for ethical awareness in software development varied to some extent.

3.5 Translating studies into each other

Translating studies into each other involves an interpretive process of comparing their findings in a predetermined order [48] In this study, the aim was to bring together useful constituent elements into concept categories required to implement practices that support ethics awareness in software development based on the four analysed studies. Considering the findings of the individual studies during translation is a useful approach [47] as we applied it here. The studies were translated into one another based on the recommended translation methods. The studies were translated in the same order as they appear in Table 3. Seeing that the studies' s focuses were similar, it was possible to conduct a reciprocal translation, then concluded with a line of argument. The reading by one reviewer resulted in five concept categories, whose applications were similar across all studies, and thus carried the same meaning. This also led to the identification of correspondences in the findings of the individual studies in line with the emerging concepts from the reading. The other reviewer verified the process and its outcomes, including the concepts, the completeness of their categories and the grouping of constituent elements.

The studies concurred on the concepts defining the intervention mechanism for ethics awareness, which enabled the listing of broader concepts. The main concepts included ethics codes, stakeholder participation, software process embeddedness, ethics impact assessment, and human and technical support. For each concept, the supporting element from each study was identified. In Table 3, the constituent elements are labelled Rn, Dn, Cn, and En, denoting the first letter of the studies' proposed interventions (RESOLVEDD, DSS4EM, CoESDLC, and ECCOLA), respectively, and the number (n) identifying the element associated with the concept. For example, in labelling the stakeholder involvement or participation concept in Table 3, stakeholders were identified as R7 in the first study, whereas in the last study, they were identified as E10. For each study, the corresponding elements are listed in each concept category. The limited number of four studies made the translation manageable.

3.6 Synthesizing the data

The synthesis of the studies includes organising the data from the included studies to achieve a significant outcome larger than the individual studies [47]. An organisation of the concept categories and constituent elements was developed from the extracted data for the analysed studies, as presented in Figure 5. This also shows how the constituent elements map to the five concept categories, enabling the formulation of the proposed framework. This classification provides a better understanding of how ethics awareness can be improved in software development by integrating the various components of the framework. Considering the evolving ethical landscape of software, the implementation and testing of the conceptual framework may require contextualisation to the needs of software development domains.

3.7 Reporting the results of the synthesis

The paper analysed studies that met the criteria for synthesis to inform evidence-based ethics-aware software engineering practice. This culminated in the formulation of a framework intended to guide practice and research toward the further development of practical tools to enhance ethics awareness and adherence in software development. Hence, as part of the study's objective, we found that publishing the outcomes of this study is suitable for both software engineering practice and research [48].

3. RESULTS AND DISCUSSION

A discussion to provide insights on the results and findings from selected materials for the study, and the extracted data is explored in the subsequent sections. The data extracted from the studies, as presented in Table 3 provides demographic details of the included studies and data elements of interest for analysis and synthesis to answer the study's research questions, respectively.

In terms of the selected studies overview, the selected studies comprise two conference papers [49] and [50] and two journal papers by [51] and [52]. In comparison to the larger body of knowledge, remaining with only four articles after the selection process exhibits limited qualifying qualitative studies that were undertaken to provide practical mechanisms and tools to assist software stakeholders in navigating ethics in software development. In addition, only one of the studies provides an ethics mechanism for

general software engineering, whilst the majority are oriented to the development of software in the artificial intelligence domain. Although grappling with software engineering ethics has been an issue for some time and the contribution of qualitative studies is impactful, the limited number of qualitative studies addressing this ethics challenge is a concern. Therefore, insufficient research for generating accompanying adaptable ethics integration mechanisms for the evolving software landscape, characterised by the proliferation of transformative technologies that can radically impact society, is a continuing challenge

Table 3. Identified studies' demographic details and main concepts

	1	2	3	4
Authors	Vakkuri et al. (2019) [49], Conference	Nussbaumer et al. (2021) [51] Journal	Karim et al. (2017) [50], Conference	Vakkuri et al. (2021) [52], Journal
Domain	Artificial Intelligence/Autonomous System	Information Systems Development (Decision Support Systems)	Software Engineering	Artificial Intelligence
Sample	5 student projects of 4-5 students	Researchers and practitioners in public health and EM, public and local population, project team members, focus group participants	17 software engineers	5 teams of 4-5 students (2018)27 teams of 3-4 students (2018/9)2 software development team members 8 researchers 3 company cases (each with 2 developers and 1 project owner), one of the cases had a consultant

	1	2	3	4
				ICT researchers
Stakeholder involved	(R7) Designer, Product and End-users	(D9) Users, project team, health care experts, academics	(C8) Software engineers	(E10) Users, researchers, development teams
Proposed mechanism for ethics support	Ethically Aligned Design using (R1) RESOLVEDD strategy	Framework of integrating (D1)Ethics-by-design approach in Decision Support Systems for Emergency Management (DSS4EM)	A framework for the alignment of ACM/IEEE code of ethics principles (C1) with systems development life cycle (CoESDLC)	ECCOLA Method (modular tool) (E1)
Artefact (or features of the artefact) developed in the study	Application of the RESOLVEDD strategy to the development of prototypes	Ethical stage-gates (ESG)	Classification of ACM/EEE code of ethics principles according to the phases of the systems development life cycle	ECCOLA cards (physical card deck)
Stage of intervention (Ex ante, intra, ex-post)	(R2) Ex ante	(D2) Ex ante, intra and (D3) ex-post	(C2) Ex ante	Ex ante (E2)
Software process supported	Not stated	Agile (D9)	Traditional (C7)	Agile (E9)
Values And Principles	(R3)Commitment to ethical development, (R4)Transparency	(D4)Transparency, (D5) responsiveness, (D6)	Four ACM/IEEE code of ethics principles: (C3) Public, (C4)	(E3) Analyse, (E4) Transparency, (E5) safety and security, (E4)

	1	2	3	4
	of the process, (R5) accountability, an activated (R6) sense of responsibility, and acceptance of responsibility	reasonableness, data (D7) protection and privacy, (D8) Justice and fairness	Client, and (C5) Employer and (C6) Product	fairness, (E6) data, (E7) agency and oversight, (E8) wellbeing and (E9)accountability
Human and Technical Support	(R8) Existence of an ethical tool supports ethical-decision making (R9) ethics enforcement	(D10) Supports decision-making, train users, (D11) evaluate technology artifacts with ethics lens, (D12) ethics team support technical team, (D13) end-user training (awareness)	(C9)Provides simplified tool for ethics decision-making (10) Ethics awareness	(E11) Creates ethics awareness, (E12) Provides a practical and technical platform and tools for ethics decision-making, (E13) user training workshops
Theory(ies) adopted	CART – Commitment, Accountability, Responsibility and Transparency Ethically-Aligned Design	ethics-by-design approach, ethical impact assessment	Systems Development Life Cycle, Software Engineering, Code of ethics	RESOLVEDD strategy for Stakeholder analysis/Ethical analysis, Ethically-Aligned Design, EU AI, HLEG, The Essence Theory of Software Engineering?

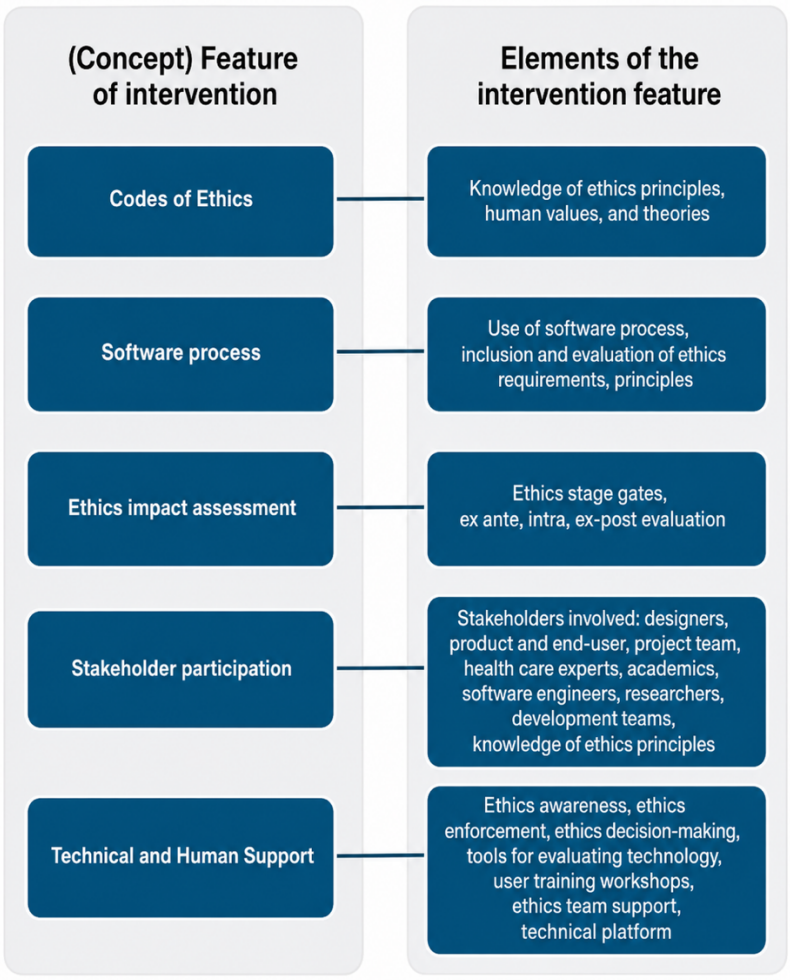

Figure 3. Summary of concepts and constituent elements

1) Existing mechanisms and associated components to support ethics in software development

To answer RQ1, the extracted data present the demographic details of the selected studies, providing contextual information on their relevance to the study and the main concepts identified. The analysis of the articles shows that the mechanisms offered for ethics-awareness and adherence include (1) RESOLVEDD-Strategy [49], (2) Decision Support Systems for emergency management [51], (3) Integrating Code of Ethics into Software Development Life Cycle [50] and (4) ECCOLA [52] as presented in Table 3. For easy reference in this study, mechanisms 2 and 3, are abbreviated or code-named DSS4EM and CoESDLC, respectively.

The RESOLVED strategy, as described by [45], provides a nine-step approach to software development ethics, adopted from business ethics. In terms of how it is applied as an intervention in the form of an ethical tool to support ethical considerations in software development, it requires that its use be included as a design requirement and as part of ethics value alignment. The tool design in the study adopted Commitment, Accountability, Responsibility and Transparency principles to support the Ethically Aligned Design. The implementation of this mechanism was tested in the context of developing Artificial Intelligence/Autonomous Systems (AI/AS). On the other hand, the DSS4EM, developed by [46], provides a framework for embedding ethical considerations into system design. The framework was applied in the implementation of the S-HELP decision support system for emergency management. It took into consideration Transparency, Responsiveness, Reasonableness, data protection and privacy, justice and fairness and precautionary ethical values [46]. The similarities between these ethical intervention mechanisms are that they both espouse ethical design and are based on ethical values and principles.

CoESDLC was conceptualised by [52] to provide a framework for mapping code of ethics principles across the software development lifecycle phases. It allows ease of reference for those involved in the various phases of the lifecycle. Lastly, the ECCOLA method by [52] assists developers in implementing ethical principles of Artificial Intelligence by incorporating AI ethics into the development process to achieve ethical AI systems. The method was tested in an iterative development setting, applying certain AI principles, including transparency, fairness, accountability, etc., similar to the RESOLVEDD strategy and DSS4EM. Therefore, ECCOLA and RESOLVEDD are oriented to support ethics awareness and adherence, specifically in the AI domain, and require AI-specific orientation rather than the broader software engineering ethics. Based on the results, the implementation of ethical interventions in the AI domain is more prevalent, compared to one study covering general software engineering ethics and the other study focusing on supporting ethical decision-making in disaster response or emergency support systems.

The metadata were analysed to identify the features and components of the mechanisms presented by these studies. Metadata analysis enables the researcher to reinterpret the original qualitative studies' findings [29]. The commonality identified amongst these mechanisms is that they follow ethical principles informed by context, such as design for

AI, AS, emergency support or even general software design, and use these principles to assess ethics at various stages of software development. Therefore, from the perspective of these studies, ethics assessment is a critical feature of any intervention aimed at promoting ethics awareness in software development. Furthermore, the analysis shows the need to include features that enable software ethics integration from conceptualisation through to software use. This concretises the need to solicit ethical input from stakeholders and address them accordingly. Therefore, stakeholders' involvement in ethics endeavours across the software process should be supported. In addition, the studies show that ethical considerations are based on the application of common and domain-specific ethical principles, primarily drawn from codes of ethics issued by regulatory and professional bodies. Furthermore, they provide for ethics impact assessment using ethics stage gates at various points of each phase of the software process. This organisation embeds ethics throughout the software process, thereby positioning ethics at its core.

In subsequent metadata analyses, the study evaluated the underlying assumptions of the data analyses of the participating articles. This has assisted in comparing the quality of the data used and in synthesising the findings from the selected articles. In terms of transferability attributes, all are found to be transferable. For example, the framework created by [51] within the context of Decision Support Systems for Emergency management, this approach can be transferred to any software development domain to guide the development, application, and assessment of the ethics-by-design approach, which is the same emphasis as the ECCOLA method [52]. This ensures that ethics are part of the software requirements before development. In the same vein, we observed that the application of CoESDLC approach can be adapted to assist in any software development domain by mapping and customising the applicable ethics principles to each stage of the adopted software development process.

The processes described in the methodology section and the extracted data enabled comparison of the selected studies' findings. Their analysis and synthesis show that the major concepts for achieving ethical software development are codes of ethics, stakeholder participation, embedding ethics practices into the software process, ethics impact assessment, and human and technical support.

2) The preliminary framework for ethics-aware software engineering practice

Following the answering of RQ1, we conducted a thorough review of the articles in this study, using the identified concepts and the grouping of their constituent elements to define the intervention mechanism for ethics in software development, and we identified how they can inform the different components of ethical software development. The components of the ethics-aware software engineering practice framework that emerged from this study, as summarised through the concept categories, are shown in Figure 4. The code of ethics and technical and human support are commonly a foundation of organisational support. In terms of operationalising the framework, the ethics impact assessment, embedding ethical practices within the software process, and stakeholder participation are at the core of the implementation, regardless of the software lifecycle process or methodology used. Therefore, we have found that the concepts identified and synthesised from the individual studies that provide mechanisms for ethics interventions led to the formulation of the framework. In Figure 4, we present the proposed conceptual framework, followed by its discussion.

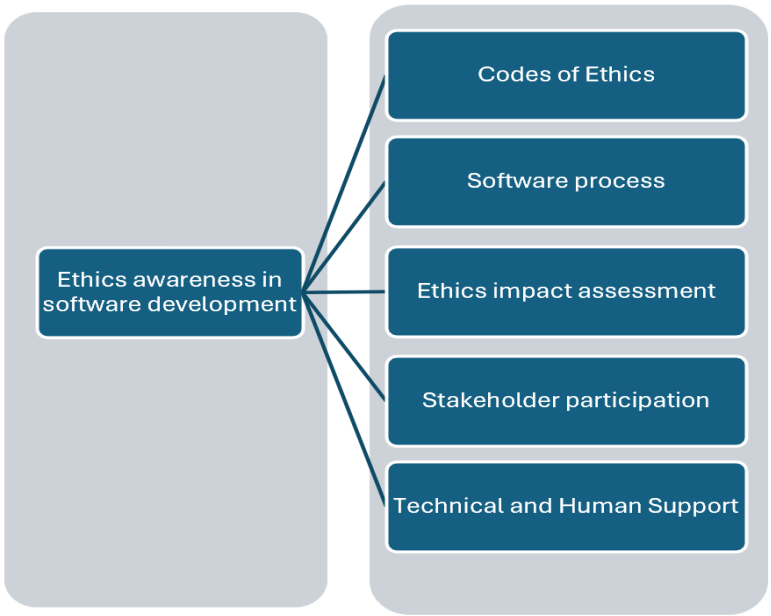

Figure 4. Preliminary framework for ethics-aware software engineering practice

a) Codes of Ethics

All the selected and analysed articles indicate that identifying ethical principles to guide and support the ethical development of software is important. The principles are derived from reliable, popular sources, such as codes of ethics published by various regulatory

and professional bodies. However, the principles may differ according to the domain of application, ethical issues, and stakeholder needs. For example, [51] for emergency management decision support systems identified fairness, transparency, privacy, responsiveness, reasonableness, data protection, justice and precaution, whilst [49] for the development of artificial intelligence platforms, consider transparency, safety and security, fairness, agency, oversight and accountability, amongst others, as relevant principles. The studies show that principles from organised bodies, such as the ACM/IEEE Joint Code of Ethics and the EU AI HLEG, are useful for guiding ethical software development. Codes of ethics and principles are important instruments that provide suitable guidelines to support software stakeholders in various software development activities, including decision-making [20], [53], [54]. Furthermore, in support, studies by [55] and [56] show that codes of ethics can significantly influence ethical conduct and ethical decision-making in the workplace.

b) Software stakeholder participation

One of the included studies, [51] specifically shows that the application of the ethics-by-design approach requires stakeholder involvement in order to achieve ethical development and use of a system. In another example, [49] refers to Ethically Aligned Design as having empowered developers to renew their sense of responsibility, whilst the study by [52] indicates that using these mechanisms increases users' awareness of various ethical issues and promotes ethical discussion within the team. Furthermore, the study by [50] demonstrated the successful classification of ethical principles according to the software development stages. This can help those carrying out tasks across the various stages of the software development process be aware of the ethical responsibilities entrusted to them, as prescribed by the guiding principles for those stages. In affirmation, a study by [57] demonstrates that several stakeholders have varying ethical concerns and interests; hence, their inclusion in software activities is crucial to successful software development. In reflection, stakeholder engagement is lauded as one of the practices for identifying and mitigating risks for improving computing project success [58]. This approach becomes more powerful in enhancing ethics in software development when integrated into the software process [59].

c) Embedding ethics into the software process

As indicated earlier, the software process comprises all the activities and procedures used to develop software products. Therefore, to allow for the ethical creation of these software products, all the analysed articles show that embedding ethics into software development is vital. Some of the analysed articles provide a detailed approach to embedding ethics into the software process, whilst others are less detailed. For example, [48] [52] expresses that "to this end, ECCOLA is intended to help organisations develop more ethical AI systems by making AI ethics issues a part of the development process" whilst [47] states that "providing a new classification of the software engineering code of ethics based on the software development life cycle phases can help software engineers better understand, apply, control and monitor software development project ethical practices." Integrating ethics and associated practices into technical activities at each stage of the process can support ethical software development. The same practice is demonstrated in a study by [11] in the way ethics can be integrated into an agile development framework.

d) Ethics impact assessment

The concept of ethics impact assessment emerged as important in the participating articles. This is supported by a study by [51], which suggests that ethical considerations should be a proactive exercise from the beginning to the end of the product life cycle to achieve normatively desired artefacts. For example, the study by [51] adds three stages at which ethical impact assessment should be conducted. The evaluation can also be conducted on the software process itself. This evaluation should be conducted in a traceable and transparent manner using relevant tools and checklists. Constructive alignment between ethical requirements and their implementation is important to enable evaluation through backwards tracing across all stages of the software process. In concurrence with [56], this can be done to ensure the software artefact aligns with the organisation's strategic ethical objectives and functions ethically to meet user needs. However, it is important that the exercise is not reduced to a tick-box activity, but is contextualised to ensure suitable compliance [8]. Therefore, applying ethics impact assessment has been a useful practice in ensuring that ethical guidelines are followed and proof to that is documented and verifiable. [60]. This approach greatly supports the element of governance various forms of technologies, including the development of the newer and pervasive technologies [61].

e) Human and technical support

All the analysed studies concur that human and technical support factors can impede adherence to ethical principles in software development. The support aspects arising from the studies include ethics awareness, commitment, accountability and responsibility, and the availability of supporting technical tools and platforms. Therefore, organisations should provide meaningful and impactful platforms for raising awareness, enabling all stakeholders to recognise and deal adequately with ethical issues [9]. In addition, the availability of tools, such as methodologies and ethics assessment tools, requires organisations to provide the technical support needed to enable stakeholders to apply them effectively to achieve ethical software development. Findings from a study by [13] show success in integrating ethics when supporting tools and conducive environments are provided to software stakeholders.

4. CONCLUSION

To support evidence-based software engineering practice, specifically in ethics awareness, this paper presents a qualitative meta-synthesis of a proposed conceptual preliminary framework for ethics-aware software engineering. This is achieved through the integration of components identified and reinterpreted from previous studies that sought to develop mechanisms to support ethical software development. Although the study achieved its goal, the limited number of participating studies leaves room for further exploration of additional sources to improve the currently proposed framework. Moreover, a broader empirical refinement will be conducted to assess its validity and usefulness. Considering that the framework is developed from studies primarily focused on mechanisms in the artificial intelligence domain, further adaptations may be required to apply it to software development beyond these contexts. Future evidence-based studies are required to focus on software development across broader domains, given the growing ethical concerns surrounding transformative technologies such as Artificial Intelligence, the Internet of Things, and embedded applications.

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