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Analysis of the Integration of Halal Concepts in the Science Curriculum and Teaching: A Case Study at Al Kamal NW Narmada Islamic Junior and Senior High Schools

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Abstract

This study examined the potential integration of halal concepts into the science curriculum and teacher-reported instructional practices at SMP and SMA Islam Al Kamal NW Narmada. Using an embedded qualitative case-study design, the study combined researcher-developed curriculum mapping with written responses from four purposively selected science teachers representing integrated science, Biology, Chemistry, and Physics. Data were analysed through qualitative content analysis, thematic coding, and cross-source comparison. The findings identified the strongest opportunities for integration in topics related to material sources, food and nutrition, the digestive system, food additives, product composition, microorganisms, fermentation, biotechnology, health, and production processes. Teachers also identified additional links through acids and bases, solutions, colloids, carbon compounds, quantities, measurement, and product observation. Reported practices included presenting examples of halal and non-halal products, examining labels and ingredient lists, observing products available in the community, and conducting simple practical activities such as pH testing. However, the reported implementation remained largely contextual and did not yet demonstrate systematic engagement with evidence evaluation, uncertainty, argumentation, or socioscientific decision-making. The study also highlights the need to distinguish scientific analysis from formal halal determination, as laboratory evidence alone cannot establish halal status without traceability, process documentation, and authorised certification. Overall, halal concepts offer a relevant interdisciplinary and socioscientific context for science learning, provided that integration is conceptually accurate, pedagogically structured, and supported by appropriate resources, teacher professional development, and collaboration with Islamic Education teachers. Further research should include classroom observations and direct assessment of student learning outcomes across diverse Islamic secondary school contexts.

Keywords: Halal concepts; Science curriculum; Science education; Islamic secondary schools; Scientific literacy

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INTRODUCTION

Halal is a fundamental concept in Muslim societies because it provides a normative basis for determining whether materials, products, and human activities are permissible according to Islamic principles. In the context of consumption, Islam requires products to be not only halal but also *thayyib*, referring to qualities such as wholesomeness, cleanliness, safety, nutritional value, and freedom from harm (Kementerian Agama Republik Indonesia, 2019). Halal should therefore not be understood solely as a binary classification of what is permitted or prohibited. It also concerns the origins of ingredients, product composition, processing methods, hygiene, safety, benefits, and the possible effects of production and consumption on human health and the environment.

Rapid developments in food technology, pharmaceuticals, cosmetics, and biotechnology have made the assessment of halal products increasingly complex. Modern products may contain gelatin, emulsifiers, enzymes, flavourings, colourants, processing aids, microbial growth media, and other compounds whose origins are not readily identifiable by consumers. This complexity is also evident in halal cosmetics, in which the permissibility of ingredients, production processes, contamination control, and analytical testing must be considered (Sugibayashi et al., 2019). Halal integrity is determined not only by primary ingredients but also by processing equipment, production procedures, storage, transportation, distribution, and the possibility of cross-contamination. Consequently, halal integrity must be maintained throughout the supply chain, from raw-material selection to the delivery of the final product to consumers (Tieman, 2011; Nakyinsige et al., 2012; Soon et al., 2017). Recent studies have further shown that halal production involves interactions among scientific procedures, technological processes, animal welfare considerations, religious requirements, and production efficiency (Abdullah et al., 2019; Riaz et al., 2021).

This complexity demonstrates that an adequate understanding of halal-related products requires scientific knowledge. Science can explain the origins and characteristics of materials, the structure and properties of substances, microbial activity, fermentation, enzyme functions, chemical transformations, nutritional composition, product safety, and analytical testing. Scientific investigation also shows that the characteristics of a product cannot always be established through visual observation. Reliable evaluation may require valid information, measurement, laboratory analysis, and the investigation of ingredient sources and manufacturing processes. Nevertheless, scientific testing alone cannot formally determine the halal status of a product. Formal determination also requires documentary traceability, examination of the complete production process, compliance with applicable halal standards, and reference to authorised certification institutions. Distinguishing scientific evidence from formal religious and regulatory determination is therefore essential when halal issues are discussed in science education.

Education has a strategic role in developing students' ability to engage critically and responsibly with halal-related information. Junior- and senior-secondary students are active consumers of food, beverages, medicines, cosmetics, and personal-care products. They receive product information through packaging labels, advertisements, social media, online marketplaces, and other digital platforms. However, recognising a halal logo does not necessarily indicate an ability to interpret ingredient lists, investigate material sources, understand manufacturing processes, assess product safety, or evaluate information credibility. Access to digital information does not automatically lead to informed judgment because individuals may encounter incomplete, misleading, emotionally persuasive, or unsupported claims (Howell & Brossard, 2021; Ecker et al., 2022).

The spread of misinformation in digital environments further strengthens the need for evidence-evaluation skills. Research has demonstrated that the interpretation of scientific and health information may be influenced by prior beliefs, source credibility, emotional responses, and repeated exposure to claims (Loomba et al., 2021; van der Linden, 2022). Interventions that direct attention to accuracy or expose individuals to common manipulation strategies may improve their ability to distinguish reliable from unreliable information (Pennycook & Rand, 2022; Roozenbeek et al., 2022). In the context of halal products, students therefore need more than factual knowledge about permitted and prohibited ingredients. They also require the ability to identify information sources, examine evidence, recognise uncertainty, and avoid drawing conclusions that exceed the available data.

These conditions highlight the importance of connecting halal literacy with scientific literacy. Halal literacy can be understood as the ability to access, comprehend, evaluate, and use halal-related information when making decisions. In educational settings, students should be encouraged to formulate questions, read labels, compare product compositions, investigate ingredient origins, assess source credibility, recognise the limitations of evidence, and develop justified conclusions. These competencies correspond with scientific literacy, particularly the ability to explain phenomena scientifically, evaluate scientific inquiry, and interpret data and evidence (OECD, 2019). Contemporary scientific literacy also includes understanding how scientific knowledge is produced, assessing scientific claims, and using evidence in personal and social decision-making (Elhai, 2023).

Science education provides substantial curricular opportunities for examining halal-related issues because many science topics are connected to products and problems encountered in students' everyday lives. At the junior-secondary level, science is taught as an integrated subject encompassing living-organism classification, substances and their properties, food and nutrition, the digestive system, additives, human health, environmental pollution, energy, and biotechnology. These topics may provide entry points for discussing food sources, product labels, nutritional quality, food additives, fermentation, hygiene, product safety, and environmental responsibility.

At the senior-secondary level, science is differentiated into Biology, Chemistry, and Physics. Relevant topics may include microorganisms, enzymes, fermentation, metabolism, genetics, biotechnology, acids and bases, solutions, colloids, carbon compounds, quantities and measurement, temperature, energy, and processing technologies. Integrating these disciplinary perspectives may enable students to examine a product through its biological sources, chemical composition, physical characteristics, measurement procedures, and production technology. An integrated approach is particularly appropriate for complex real-world problems that cannot be adequately explained through a single scientific discipline (Ortiz-Revilla et al., 2022).

Using halal-related issues as learning contexts may help students recognise that science is not isolated from religion, health, technology, ethics, the environment, or social life. Issues involving food additives, fermented products, vaccines, medicines, cosmetics, genetic engineering, and product safety contain scientific dimensions while also involving religious norms, ethical considerations, economic interests, and social consequences. Communication concerning food products and safety must also consider how consumers understand risks, interpret evidence, and participate in decisions rather than merely receive technical information passively (Kasza et al., 2022).

Halal-related cases can therefore be approached as socioscientific issues because they involve interactions among scientific knowledge, social interests, values, ethics, and decision-making (Zeidler et al., 2005). Within such an approach, students may be encouraged to examine evidence, compare claims, conduct measurements, formulate arguments, identify uncertainty, and consider multiple perspectives. However, these possibilities should be treated as pedagogical potential rather than demonstrated educational effects. The present study did not measure students' scientific literacy, critical-thinking skills, decision-making competence, or learning outcomes.

Previous halal studies have predominantly examined material authentication, detection technologies, certification, consumer behaviour, product safety, and supply-chain integrity. Nakyinsige et al. (2012), for example, examined halal-authenticity issues in meat and meat products, whereas Tieman (2011) and Soon et al. (2017) emphasised the maintenance of halal integrity throughout supply-chain processes. More recent research has continued to demonstrate that halal-related decisions involve complex relationships among materials, processing technologies, animal welfare, religious principles, and regulatory requirements (Riaz et al., 2021). These studies provide an important foundation for understanding halal-product complexity but do not directly explain how halal issues are represented within school science curricula or interpreted by science teachers.

In educational research, the integration of Islamic values into science teaching has generally been discussed at a broad conceptual level. Studies that specifically map opportunities for integrating halal concepts across junior- and senior-secondary science curricula and connect curriculum analysis with the perspectives of teachers from different science disciplines remain limited. Curriculum-document analysis alone cannot adequately explain how curricular opportunities are understood or translated into classroom practices because teachers' decisions are influenced by disciplinary knowledge, religious understanding, teaching experience, available resources, and institutional conditions. Conversely, teacher interviews without curriculum analysis may not provide a sufficient basis for identifying substantive relationships between halal concepts and specific science topics.

The present study addresses this gap by examining curricular opportunities alongside teachers' perspectives within one Islamic educational setting. Its novelty lies in combining an analysis of junior- and senior-secondary science materials with the perspectives and reported practices of integrated-science, Biology, Chemistry, and Physics teachers. Halal is not positioned merely as a religious message added to science instruction. Instead, it is examined as a potential scientific and socioscientific context for discussing ingredient sources, product composition, biological and chemical processes, measurement, health, technology, environmental responsibility, and evidence-informed decision-making. The comparison between junior- and senior-secondary levels is intended to identify differences in curricular scope and possible levels of conceptual depth rather than to generalise teaching practices beyond the investigated case.

Accordingly, this study addresses three questions: (1) how can halal concepts be represented within science topics at junior- and senior-secondary levels; (2) how do science teachers understand and report the integration of halal concepts into their teaching; and (3) what challenges and forms of support do teachers identify? This study aims to analyse opportunities for integrating halal concepts into the science curriculum and teacher-reported practices at Al Kamal NW Narmada Islamic Junior and Senior High Schools. Specifically, it identifies science topics with substantive connections to halal concepts, compares the characteristics of these connections across educational levels, explores teachers' understandings and reported experiences, and formulates preliminary implications for developing science learning that incorporates halal-related scientific and socioscientific contexts.

METHOD

Research Design and Case Boundaries

This study employed a qualitative embedded case-study design to examine opportunities for integrating halal concepts into science education and teachers' reported experiences of incorporating halal-related issues into science teaching. A case-study design was selected because the phenomenon was investigated within a clearly bounded institutional context in which curriculum interpretation, teachers' disciplinary perspectives, and the Islamic educational environment were closely interconnected (Yin, 2018).

The bounded case was the integration of halal concepts into science education within the Al Kamal NW Narmada Islamic educational environment in West Lombok, West Nusa Tenggara, Indonesia. The case comprised two embedded educational units: Al Kamal NW Islamic Junior High School and Al Kamal NW Islamic Senior High School. These schools were treated as embedded units within a single institutional case because they operated within the same Islamic educational environment and shared a common orientation towards integrating religious values into education. Nevertheless, the junior- and senior-secondary units were initially analysed separately before a cross-level comparison was undertaken.

The study examined two dimensions of the case. The first concerned curricular opportunities for connecting science topics with halal-related scientific issues. The second concerned teachers' understandings, reported teaching practices, instructional suggestions, perceived constraints, and required support. The study did not involve classroom observations, student interviews, analysis of student work, or measurement of student learning outcomes.

Accordingly, statements concerning classroom implementation are presented as teacher-reported practices rather than independently observed teaching practices.

At the curriculum level, the units of analysis were science topics taught at the junior- and senior-secondary levels. At the teacher-response level, the units of analysis were meaning units contained in participants' written responses, including statements concerning the meaning of halal, its relevance to science, potentially related topics, reported instructional practices, implementation constraints, and forms of support required by teachers. The study was conducted from January to March 2026.

Research Setting and Participants

The study was conducted at Al Kamal NW Islamic Junior High School and Al Kamal NW Islamic Senior High School in Narmada, West Lombok Regency, West Nusa Tenggara, Indonesia. Both schools implemented the *Kurikulum Merdeka* during the study period. At the junior-secondary level, science was taught as an integrated subject, whereas at the senior-secondary level, science was organised into Biology, Chemistry, and Physics.

Four science teachers were selected through purposive sampling. Participants were required to meet the following criteria: (1) actively teaching integrated science, Biology, Chemistry, or Physics at one or both participating schools; (2) having experience implementing the curriculum used by the schools; (3) having taught topics that could potentially be connected with halal-related issues; and (4) being willing to provide written information for the study.

The participants consisted of one junior-secondary integrated-science teacher, one teacher who taught both junior-secondary integrated science and senior-secondary Biology, one senior-secondary Physics teacher, and one senior-secondary Chemistry teacher. The sample was not intended to represent science teachers in general or to support statistical generalisation. Instead, participant selection was intended to obtain case-specific disciplinary coverage across the science subjects available within the research setting.

To protect participants' identities, the teachers were assigned the codes G1–G4. G1 represented a junior-secondary integrated-science teacher; G2 represented a junior-secondary integrated-science and senior-secondary Biology teacher; G3 represented a senior-secondary Physics teacher; and G4 represented a senior-secondary Chemistry teacher.

Table 1. Participants' disciplinary roles

Code	Educational level and subject	Contribution to the study
G1	Junior-secondary integrated science	Provided a junior-secondary perspective on the relationship between halal concepts and integrated-science topics.
G2	Junior-secondary integrated science and senior-secondary Biology	Provided a cross-level perspective on the relationships among halal, health, biological systems, and biotechnology.
G3	Senior-secondary Physics	Provided perspectives on measurement, product observation, and production technology.
G4	Senior-secondary Chemistry	Provided perspectives on product composition, properties of substances, chemical analysis, and laboratory activities.

Data Sources

The study used two sources of data: a curriculum-topic inventory and teachers' written responses to a semi-structured questionnaire.

The curriculum-topic inventory covered integrated science topics for Grades VII–IX and Biology, Chemistry, and Physics topics for Grades X–XII. The inventory was developed by the researchers from the science content implemented by the participating schools under the *Kurikulum Merdeka*. It recorded the educational level, grade, semester, science topic, relevant scientific concept, potential halal dimension, and analytical justification for the identified relationship.

Because the halal–science mapping matrix was produced by the researchers during the analytical process, it was treated as an analytical product rather than as an independent source for triangulation. Its purpose was to organise and document the reasoning used to identify science topics with substantive connections to halal-related issues.

The second data source consisted of written responses from four science teachers to a semi-structured questionnaire. The responses addressed teachers' interpretations of halal, the relevance of halal to science education, potentially related curriculum topics, reported teaching experiences, suggested instructional activities, implementation constraints, and forms of professional or institutional support.

Research Instruments

The researchers served as the primary instruments for selecting, organising, coding, and interpreting the data. Two supporting instruments were used: a curriculum-analysis sheet and a semi-structured written questionnaire.

The curriculum-analysis sheet contained columns for educational level, grade, semester, science topic, scientific concept, potential halal dimension, inclusion or exclusion decision, and the rationale for classification. A distinction was maintained between science content included in the curriculum inventory and pedagogical possibilities proposed by the researchers.

The semi-structured questionnaire consisted of 15 open-ended questions. The questions addressed participants' teaching assignments, the curriculum implemented by the schools, student characteristics, the meaning of halal in students' everyday lives, the relevance of halal to science education, science topics perceived as closely related to halal, potential topics at junior- and senior-secondary levels, relationships among food, nutrition, digestion, halal, and *thayyib*, the relevance of additives, product composition, microorganisms, fermentation, enzymes, and biotechnology, previous experience of discussing halal-related issues, reported instructional activities, implementation constraints, possible learning activities, and support required by teachers.

The open-ended format enabled participants to provide explanations and examples based on their disciplinary backgrounds and teaching experiences. Because the data were submitted in written form, no audio recording or oral transcription was required.

Data-Collection Procedures

Data collection was conducted in two stages. The first stage involved compiling and analysing the science-topic inventory. Science topics for Grades VII–IX and Grades X–XII were identified and entered into the analytical matrix. Each topic was then examined using predetermined inclusion and exclusion criteria.

The identification of halal-related curricular opportunities did not depend on the explicit occurrence of the term "halal." Instead, each topic was examined for a substantive and scientifically explainable relationship with one or more of the following dimensions:

1. biological or chemical sources of materials;
2. product ingredients and composition;
3. food, nutrition, health, and product safety;
4. additives, microorganisms, enzymes, and fermentation;
5. biotechnology and biologically derived products;
6. measurement, testing, processing, storage, and production technology; and
7. hygiene, contamination, waste management, and environmental responsibility.

A topic was included when its relationship with a halal-related issue could be explained through the scientific concepts associated with that topic. A topic was excluded when the proposed relationship depended only on a general religious or moral statement and lacked a clear scientific basis. This procedure identified 20 junior-secondary science topics and 21 senior-secondary science topics with potential substantive relationships to halal concepts.

For each included topic, the researchers recorded the scientific basis for its relationship with halal-related issues. Topics with weak, indirect, or ambiguous connections were reviewed before a final inclusion decision was made. Classification as relevant indicated a curricular opportunity for discussing halal-related scientific issues; it did not indicate that the topic had already been taught using a halal context.

The second stage involved administering the semi-structured written questionnaire individually to the four participating teachers. All participants received the same 15 core questions, allowing responses across educational levels and science disciplines to be compared. The questionnaire was completed in Indonesian. Participants' original wording was retained during the initial analysis. Quotations selected for reporting were edited only for spelling, punctuation, and readability without altering their substantive meaning.

Data-Analysis Procedures

The curriculum inventory and teachers' written responses were analysed separately before being integrated at the interpretive stage. Curriculum data were examined using qualitative content analysis (Krippendorff, 2018), whereas teachers' responses were analysed using thematic analysis informed by Braun and Clarke (2006). The processes of data reduction, organisation, comparison, and conclusion drawing were also guided by the analytical principles proposed by Miles et al. (2014). The overall analytical procedure is summarised in Figure 1.

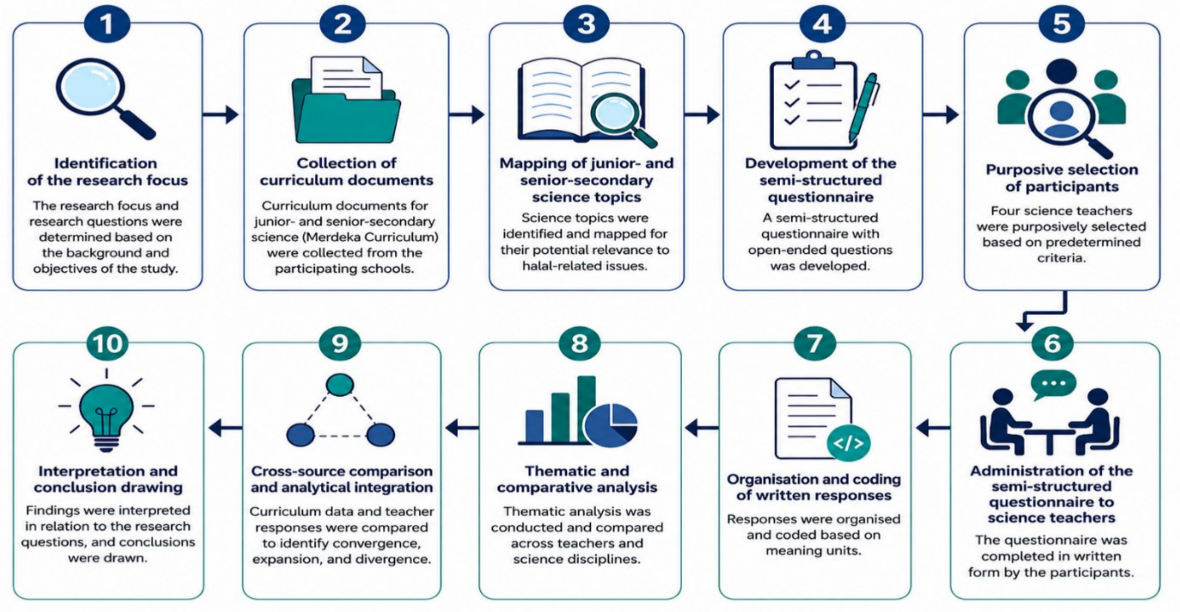

Figure 1. Data-collection procedure

The curriculum analysis employed a hybrid deductive–inductive approach. Initial deductive categories were derived from the research questions and the conceptual relationships among halal, material sources, product composition, food and health, microorganisms, biotechnology, production technology, and environmental responsibility. Additional categories were developed inductively when particular curriculum topics could not be adequately represented within the initial framework.

The analysis began with the compilation of science topics from the junior- and senior-secondary levels. Each topic was entered into an analytical matrix and screened using the predetermined inclusion and exclusion criteria. Topics that met the criteria were assigned to one or more halal-related categories, and the scientific rationale for each classification was documented. Topics with indirect, weak, or ambiguous relationships were reviewed before a final decision was made. The included topics were subsequently grouped into broader thematic categories, and their characteristics were compared across the two educational levels.

Teachers' written responses were analysed through repeated reading, identification of meaning units, initial coding, comparison of codes, category development, theme construction, and interpretation. The coding process combined deductive codes derived from the research questions with inductive codes generated from the participants' responses. Initial codes included the meaning of halal, its relevance to science education, potentially related curriculum topics, teacher-reported practices, suggested learning activities, implementation constraints, teaching materials, laboratory facilities, professional development, and interdisciplinary collaboration.

Related codes were then organised into broader themes concerning teachers' understandings of halal, perceived relationships between halal and science, teacher-reported integration practices, disciplinary variation across science subjects, and the constraints and forms of support identified by the participants. Coding was conducted manually using analytical matrices and word-processing files. Each code, category, and theme was checked against the original responses to ensure that the interpretation remained grounded in the data. Responses that differed from, qualified, or contradicted the dominant pattern were retained to represent variation within the case.

After the separate analyses had been completed, the curriculum and teacher-response data were compared to identify convergence, expansion, and divergence. Throughout this process, the researchers distinguished among curriculum-based opportunities derived from the science-topic inventory, teacher-reported practices and suggestions derived from participants' written responses, and pedagogical implications developed by the researchers during interpretation.

This distinction was maintained to prevent proposed instructional activities from being presented as practices that had been directly observed in the classroom. The comparison between the junior- and senior-secondary levels was based on differences identified in the curriculum inventory and teachers' responses. When a developmental progression was inferred rather than directly supported by the data, it was presented as a pedagogical implication rather than as an empirical finding.

Trustworthiness and Researcher Reflexivity

Several procedures were used to strengthen the trustworthiness of the study. Source comparison was conducted across teachers representing integrated science, Biology, Physics, and Chemistry. Analytical comparison was conducted between the curriculum-topic inventory and teachers' written responses. However, the researcher-developed mapping matrix was not treated as an independent data source.

An audit trail was maintained through the curriculum-analysis matrix, coding records, category definitions, analytical notes, and links between interpretations and their original data sources. Code–data comparison was conducted by tracing each category and theme back to the corresponding science topic or participant response. Interpretations that lacked sufficient evidence were revised, qualified, or excluded.

Variation among participants was also considered during analysis. Differences in how teachers connected halal with health, biological processes, chemical composition, measurement, and technology were retained as disciplinary variation rather than being reduced to a single uniform perspective.

Researcher reflexivity was particularly important because the classification of science topics as halal-related involved interpretive judgement. One member of the research team was affiliated with the junior-secondary school and therefore had contextual familiarity with the research setting. This position facilitated access and contextual understanding but also created a risk that prior assumptions could influence classification and interpretation.

To reduce this risk, the researchers distinguished original science topics from their own pedagogical interpretations, documented the scientific justification for each included topic, applied the same inclusion criteria across educational levels and disciplines, and traced each conclusion to its original source. The analysis also maintained a clear distinction between scientific examination and formal halal determination. Scientific analysis was understood as supporting the examination of product materials, processes, and evidence, whereas formal halal status remained within the authority of relevant religious and certification institutions.

Research Ethics

Participation was voluntary, and all participants received information about the study's purpose, academic use of their responses, and identity protection before providing consent. No student data were collected, and the research involved neither classroom experimentation nor instructional intervention. Teachers' names were removed from analytical records and replaced with codes G1–G4, while quotations excluded unnecessary personal details. Because the study was conducted in a small institutional setting and participants held distinctive disciplinary roles, complete anonymity within the schools could not be guaranteed. Consequently, only information essential for interpreting disciplinary perspectives was reported, and potentially identifying details were omitted from the manuscript.

RESULTS AND DISCUSSION

Results

The findings are presented separately from the discussion to distinguish empirical evidence from interpretation. The results draw on the researcher-developed curriculum mapping matrix and the written responses of four science teachers representing integrated science, Biology, Physics, and Chemistry. Direct quotations were translated from Indonesian and lightly edited for spelling and readability without altering their substantive meaning.

Curricular Opportunities for Integrating Halal Concepts

The researcher-developed mapping matrix identified twenty junior-secondary science topics and twenty-one senior-secondary science topics with potential substantive connections to halal-related issues. The strength of these connections varied across topics. The most direct relationships were found in topics concerning material sources, food and nutrition, the digestive system, food additives, product composition, microorganisms, fermentation, and biotechnology. In contrast, topics related to measurement, energy, production technology, and the environment showed more contextual relationships because they required additional explanation concerning processing, safety, technological applications, or environmental responsibility.

At the junior-secondary level, the identified topics were grouped into several broad themes: sources of materials and living organisms; food, nutrition, and health; substances and product composition; microorganisms and biotechnology; production technology; and environmental responsibility. The classification of living organisms provided opportunities to examine organisms as sources of food and other consumer products. Topics on substances and their characteristics, as well as food additives, were linked to product ingredients and the origins of additional materials. The digestive system, energy in living systems, and the circulatory system were associated with food, nutrition, and health. Biotechnology showed a more direct relationship with microorganisms, fermentation, enzymes, and materials used during production.

The relationship between halal and topics such as temperature, electricity, magnetism, and energy was more indirect. These topics were relevant only when applied to contexts such as processing, storage, packaging, measurement, or production technology. Accordingly, they were not classified as inherently halal-related topics; their relevance depended on the product or production context used in instruction.

At the senior-secondary level, the mapping was more strongly represented by Biology topics, particularly biodiversity, microorganisms, human physiological systems, metabolism, genetics, and biotechnology. Food- and health-related themes appeared in the digestive system, metabolism, the circulatory system, and the immune system. Microorganism- and production-related themes appeared in bacteria, fungi, fermentation, enzymes, vaccines, and both conventional and modern biotechnology. Genetics and biotechnology also provided opportunities to examine organism sources, genetic engineering, cell culture, and recombinant products.

Opportunities related to Chemistry and Physics emerged more clearly from teachers' written responses than from the initial mapping matrix. The Chemistry teacher identified acids and bases, solutions and concentration, biochemistry, colloids, and carbon compounds as relevant topics because of their relationship with the composition and processing of food, beverages, medicines, and cosmetics. The Physics teacher associated halal-related learning with quantities and measurement through product observation and examination of composition information.

Table 2. Themes of halal integration identified from curriculum mapping and teacher responses

Theme	Junior-secondary findings	Senior-secondary findings	Nature of the relationship
Sources of materials and living organisms	Classification of living organisms and food sources	Biodiversity and organism-derived materials	Directly related to material origin
Food, nutrition, and health	Energy, digestion, food additives, and body systems	Digestion, metabolism, circulation, and immunity	Direct and contextual
Substances and product composition	Substances and their characteristics; food additives	Acids and bases, solutions, colloids, biochemistry, and carbon compounds	Directly related to composition and properties
Microorganisms and biotechnology	Fermentation and biotechnology	Bacteria, fungi, enzymes, genetics, vaccines, and modern biotechnology	Directly related to sources and processes
Measurement and production technology	Temperature, electricity, energy, and environmentally friendly technology	Quantities, measurement, testing, and processing	Contextual and supportive
Environment and responsibility	Pollution and resource use	Ecology, environmental change, and production waste	Contextual and ethical

Teachers' Understandings of Halal

All four teachers considered halal relevant to science education, although they emphasised different dimensions. G1 understood halal primarily in relation to consumption and the need to identify whether food is permissible. This perspective positioned food as the most accessible entry point for integrating halal into junior-secondary science.

> *"Halal is something that we must understand because we need to know whether the food we consume is halal or not."* (G1)

G2 defined halal as something permissible and good for consumption. The teacher associated halal with physical and spiritual health because students' well-being was understood to be closely related to the food and beverages they consumed.

> *"For students, halal means something that is permissible and good to consume, whereas haram refers to something that is not permitted to be performed or consumed."* (G2)

G3 emphasised that halal considerations applied not only to food but also to products used in everyday life. The teacher identified food and product ingredients as the aspects most closely related to science.

"Halal products are very important, particularly for Muslims, because we need to pay attention to the halal status of everything we eat and use." (G3)

G4 expressed a broader understanding of halal by relating it to how income and food are obtained, honesty, trustworthiness, and respect for the rights of others. This response extended halal beyond product consumption to include ethical conduct.

"In everyday life, halal can be related to conducting all activities in accordance with God's provisions, including how income is earned, how food is obtained, being trustworthy, not taking the rights of others, and behaving honestly." (G4)

Across the four responses, teachers' understandings reflected normative-religious, health-related, scientific, and ethical dimensions. The normative dimension concerned what was permitted or prohibited. The health dimension concerned food that was good and safe. The scientific dimension concerned material sources, composition, properties, and production processes. The ethical dimension concerned how products were obtained, honesty, trustworthiness, and responsibility.

Science Topics Perceived as Relevant by Teachers

At the junior-secondary level, G1 identified biotechnology, food additives, health, living organisms, and ecology as topics that could be connected with halal concepts. G2 identified the digestive system, food additives, biotechnology, and the reproductive system. Both teachers placed particular emphasis on food, health, additional ingredients, and biological processes.

G2 regarded the digestive system and food additives as the most directly relevant topics because they concerned the food entering the human body and the substances added to products.

"The human digestive system and food additives are relevant. Biotechnology and the human reproductive system may also be connected with halal concepts." (G2)

At the senior-secondary level, G4 identified Chemistry topics related to product properties and composition, including acids and bases, solutions and concentration, biochemistry, colloids, and carbon compounds. The teacher considered product composition and processing to be central entry points for halal-related science learning.

"The halal-related aspects most closely connected with science concern the ingredients or composition and the processing of food, beverages, medicines, and cosmetics." (G4)

G3 associated halal concepts with quantities and measurement. This perspective suggested that products could be used as objects of observation in Physics.

"The simplest Physics topics that can be connected with halal concepts are quantities and measurement. A product can be examined through the measurement and quantity of the materials used." (G3)

The teacher responses therefore broadened the range of potential topics beyond integrated science and Biology. However, the responses also showed that scientific measurement was sometimes closely associated with halal determination, even though measurement alone only provides information about physical characteristics, quantities, or other observable properties.

Teacher-Reported Integration Practices

All four teachers reported that they had discussed halal-related issues in science teaching. Because the study did not include classroom observation or the examination of lesson plans and student work, these findings are presented as teacher-reported practices.

G1 reported using examples of foods and living organisms categorised as halal or non-halal. The activity mainly involved direct explanation and the presentation of examples.

"In lessons on food substances and living organisms, I provide examples of which are halal and which are not halal." (G1)

G2 reported integrating halal concepts into lessons on the digestive system and food additives. The learning activities were connected with religious principles concerning food and beverages, the way materials were obtained, and the way food was prepared and served.

"In lessons on the human digestive system and food additives, the learning was connected with religious perspectives on the status of food and beverages and on how they should be obtained and served according to religious guidance." (G2)

This reported practice addressed not only the final product but also the processes through which food was obtained and prepared. However, the description placed greater emphasis on religious guidance and consumption behaviour than on the collection or evaluation of scientific evidence.

G3 reported a product-observation activity within lessons on quantities and measurement. Students were asked to bring products available in the community and examine the composition information.

"In lessons on quantities and measurement, students bring samples or products available in the community and examine the composition of the materials used." (G3)

This activity used everyday products as learning contexts. Nevertheless, the reported practice indicated a need to distinguish between observing composition information and formally determining halal status.

G4 reported conducting a pH-testing practical activity using mineral water, vinegar, soap, and shampoo carrying halal labels. Students examined the relationship between pH, product function, and safety.

"In lessons on acids and bases, students conduct practical work by testing the pH of mineral water, vinegar, soap, or shampoo carrying halal labels. They analyse the relationship between pH, product function, and the importance of selecting halal and safe products." (G4)

The reported activity applied Chemistry concepts and measurement data to everyday products. However, pH testing provided information about acidity, product function, and aspects of safety rather than formal halal status.

Overall, the reported practices ranged from direct explanation and the use of examples to label reading, product observation, and simple practical work. The available data did not provide sufficient evidence that the teaching practices had developed into systematic evidence-based argumentation, evaluation of conflicting sources, or socioscientific decision-making.

Learning Activities Suggested by Teachers

Teachers also proposed activities that they considered suitable for integrating halal concepts into science learning. G2 suggested analysing product composition and nutritional content, discussing preparation methods, and examining how food ingredients were obtained.

"The activities could involve examining the composition or nutritional content of food, as well as considering how the food is prepared and how its ingredients are obtained." (G2)

G4 proposed group discussion and practical work as the most feasible activities.

"The most appropriate activities for teaching halal concepts are group discussions and practical work." (G4)

G1 identified biotechnology as a potentially relevant context but did not describe a specific activity. G3 suggested substances and their characteristics, as well as the classification of living organisms, as possible contexts. These statements represented teachers' suggestions and should not be interpreted as activities that had necessarily been implemented.

Constraints and Required Support

The teacher responses indicated that the integration of halal concepts was not yet supported by systematic planning or adequate learning resources. G1 emphasised the need for instructional media and laboratory facilities.

> *"Instructional media and laboratory facilities are needed."* (G1)

G2 stated that the Islamic boarding-school environment supported the integration of halal concepts, but teachers with limited knowledge of halal and haram might experience difficulty in connecting these concepts with science.

> *"For me, because I teach in an Islamic boarding-school environment, halal concepts are highly appropriate for integration. However, teachers who have not studied them in depth may have limited understanding of halal and haram according to Islamic teachings."* (G2)

G3 identified the limited availability of teaching materials as a major constraint and emphasised the need for collaboration and professional development.

> *"There are still very few books or teaching materials that connect halal concepts with science. Collaboration between science and Islamic education teachers is needed, together with training or workshops."* (G3)

G4 similarly emphasised the need for specialised training.

> *"Teachers need specialised training on halal concepts and on how to integrate them into science teaching."* (G4)

The responses showed that teachers required support not only in substantive knowledge but also in instructional design, learning resources, media, laboratory facilities, examples of activities, and interdisciplinary collaboration.

Table 3. Forms of support identified by teachers

Area of support	Findings from teacher responses
Substantive understanding	Greater understanding of halal, *thayyib*, material sources, production processes, and the limits of scientific analysis.
Pedagogical competence	Training, workshops, and examples of integrated lesson designs.
Learning resources	Modules, books, worksheets, case studies, and practical-work guides.
Learning facilities	Instructional media, laboratories, measurement tools, and product samples.
Collaboration	Cooperation among integrated-science, Biology, Chemistry, Physics, and Islamic education teachers.
Planning	Alignment of learning outcomes, content, activities, and assessment.

Cross-Source Synthesis

Comparison between the curriculum mapping and teachers' responses showed the strongest convergence in the themes of food and beverages, the digestive system, food additives, product composition, microorganisms, fermentation, biotechnology, health, and the environment. These themes appeared in both the mapping matrix and the teachers' written responses.

Teachers’ responses extended the initial mapping in Chemistry and Physics. Acids and bases, solutions, colloids, biochemistry, carbon compounds, quantities, and measurement emerged primarily from the disciplinary perspectives of the subject teachers. By contrast, several topics included in the mapping matrix, such as magnetism, electricity, energy, and evolution, received limited support from the teachers’ responses. Their relationship with halal therefore depended more heavily on researcher interpretation and the instructional contexts that might be developed.

Taken together, the findings indicate that the strongest curricular opportunities were found in topics with direct relationships to material sources, composition, consumption, health, microorganisms, and production processes. Topics with indirect relationships required more selective use to avoid reducing halal integration to the insertion of general moral messages that were disconnected from the scientific content.

Discussion

Strength of the Relationship between Halal Concepts and Science Topics

The findings indicate that halal concepts have the strongest potential for integration into science topics that are directly related to material sources, food and nutrition, the digestive system, food additives, product composition, microorganisms, fermentation, and biotechnology. This relationship is substantively justified because the evaluation of a product involves not only its primary ingredients but also the origin of additional materials, processing procedures, microbial growth media, production equipment, storage, distribution, and the possibility of cross-contamination. Soon et al. (2017) emphasised that halal integrity must be maintained throughout the supply chain rather than being assessed solely at the level of the final product. Similarly, Fuseini et al. (2016) highlighted the importance of production procedures in determining compliance with halal principles, while Alzeer et al. (2018) linked halal and *tayyib* with food safety, quality, and wholesomeness. The relevance of scientific analysis in this area is also supported by studies on halal production technology and authenticity testing (Riaz et al., 2021; Mostafa, 2020; Rohman & Windarsih, 2020).

In contrast, the relationship between halal concepts and topics such as temperature, electricity, energy, magnetism, and production technology is less direct. These topics become relevant when they are situated within contexts involving processing, storage, packaging, measurement, or product-quality control. This finding suggests that halal-related content does not need to be inserted explicitly into every science topic. Integration should be undertaken only when a clear conceptual relationship can be established through the intended learning outcomes and relevant scientific practices. Such selectivity is necessary to prevent halal integration from becoming the addition of moral messages that are disconnected from the scientific substance of the lesson.

Halal Concepts as an Interdisciplinary Context

The teachers’ responses broadened the initial mapping, which had been more strongly represented by integrated science and Biology topics. The Chemistry teacher identified acids and bases, solutions, concentration, colloids, biochemistry, and carbon compounds as possible entry points for examining product composition and properties. The Physics teacher associated halal-related learning with quantities, measurement, and the examination of product information. These findings indicate that halal-related issues are inherently interdisciplinary because they may involve biological sources, chemical composition, physical characteristics, processing technologies, health, and environmental effects.

Interdisciplinary integration is meaningful only when each discipline retains its conceptual contribution. Biology can explain organism sources, microbial activity, body systems, metabolism, and biotechnology. Chemistry can be used to investigate composition, properties of substances, chemical change, concentration, and additives. Physics can contribute to measurement, temperature control, storage, and production technology. Kelley and Knowles

(2016) argued that meaningful integration should be organised around authentic problems while preserving the conceptual contribution of each discipline. Ortiz-Revilla et al. (2022) similarly emphasised that integrated science learning requires coherent connections among disciplines and clearly defined learning goals rather than the superficial combination of several subject terms in a single activity.

Nevertheless, the involvement of several disciplines does not imply that all relevant aspects must be taught within one lesson. Teachers may select a particular product-related issue as a context and then determine which scientific concept is most appropriate. For example, food labels may be used in junior-secondary science to identify ingredient sources and additives, whereas the same product may be analysed at the senior-secondary level through concentration, fermentation, microorganisms, or production processes.

The Boundary between Scientific Analysis and Formal Halal Determination

An important finding of this study is that teachers did not always apply a consistent boundary between the role of scientific analysis and the formal determination of halal status. Observing product composition, measuring the quantities of ingredients, or testing pH may provide information about the properties, contents, functions, and safety of a product. However, such evidence is not sufficient to establish formal halal status. Halal determination requires traceability of ingredient origins, processing aids, production procedures, equipment use, documentation, and assessment by an authorised institution.

This epistemic boundary should be incorporated explicitly into science learning. Students need to understand which questions can be addressed through experimentation and which conclusions cannot be drawn from the available data. For instance, pH testing can indicate the acidity of a product and support discussion of its function or safety, but it cannot reveal the complete origin of all ingredients. Likewise, label analysis can identify ingredients declared by the manufacturer, yet it may not explain the origin of enzymes, gelatin, emulsifiers, or processing aids. Learning activities of this kind can help students understand both the strengths and limitations of scientific evidence.

This distinction is particularly important because halal authentication often requires multiple forms of evidence. Rohman and Windarsih (2020), for example, demonstrated that molecular spectroscopy and chemometric techniques can support halal authentication, but such analytical procedures still form only one part of a broader verification process. In the same way, Riaz et al. (2021) showed that scientific and technical procedures must be interpreted alongside religious and regulatory considerations. Science education should therefore help students recognise that scientific evidence contributes to halal assessment without replacing formal religious and certification processes.

Halal Integration and the Development of Scientific Literacy

The practices reported by teachers included providing examples of halal and non-halal foods, connecting science topics with consumption rules, reading product composition, observing consumer products, and conducting pH-testing activities. These practices indicate a progression from informative teaching towards contextual and simple investigative activities. However, the data do not show that students were systematically engaged in comparing information sources, assessing uncertainty, evaluating conflicting claims, or constructing evidence-based arguments.

Contemporary scientific literacy extends beyond conceptual knowledge. Howell and Brossard (2021) argued that scientifically literate citizens must be able to evaluate information within complex digital environments. Elhai (2023) similarly defined scientific literacy as an understanding of how scientific knowledge is produced, evaluated, and applied. This broader perspective is increasingly important because students obtain product information from social media, advertising, labels, and digital marketplaces. Breakstone et al. (2021) showed that students often experience difficulty evaluating online information, while Jones-Jang et al.

(2021) found that information literacy is particularly important for identifying unreliable claims.

Accordingly, product-based learning should extend beyond recognising halal logos. Students can be asked to identify the producer of a claim, compare labels across several products, examine the credibility of cited sources, distinguish factual information from marketing claims, and explain which information remains unavailable. These activities are relevant because the acceptance of information is influenced not only by knowledge but also by prior beliefs, source credibility, repetition, and cognitive tendencies. Ecker et al. (2022) explained that misinformation persists partly because of cognitive and motivational factors. Roozenbeek et al. (2022) demonstrated that targeted interventions can improve resilience against misleading information, whereas Pennycook and Rand (2022) showed that prompts directing attention to accuracy can reduce the spread of false claims. Van der Linden (2022) likewise emphasised the importance of preventive strategies in strengthening resistance to misinformation.

Within halal-related science learning, these insights suggest that students should be trained not merely to receive product information but to interrogate it. Such activities may support the development of evidence evaluation, source criticism, and responsible decision-making. However, because the present study did not assess student outcomes, these benefits should be regarded as pedagogical potential rather than demonstrated effects.

Educational-Level Differences as a Pedagogical Progression

The junior-secondary topics identified in this study were more closely connected with concrete objects and everyday experiences, such as food, animals, product labels, additives, bodily health, and the environment. Senior-secondary topics provided greater opportunities for more complex analysis through microorganisms, metabolism, genetics, biotechnology, solutions, colloids, carbon compounds, and measurement.

However, because the study did not observe classroom instruction, these differences cannot be interpreted as evidence that junior-secondary teaching was already concrete and that senior-secondary teaching was already analytical. The pattern is more appropriately understood as a potential pedagogical progression based on differences in curricular complexity.

At the junior-secondary level, integration may begin with observing, classifying, reading labels, and connecting food consumption with health. At the senior-secondary level, activities may be extended towards composition analysis, data interpretation, production-process tracing, source comparison, and argument construction. Such progression should remain aligned with curriculum outcomes, students' developmental readiness, and the quality of available evidence.

This progression also allows the same issue to be revisited at increasing levels of complexity. For example, fermentation may initially be introduced through observable changes in food products, then later examined through microbial activity, enzyme function, process conditions, and product safety. In this way, halal-related contexts can support continuity across educational levels without repeating identical content.

Strengthening Teacher Competence and Collaboration

The reported limitations in teaching materials, media, laboratory facilities, training, and pedagogical guidance indicate that halal integration remains highly dependent on individual teacher knowledge and creativity. This condition may produce variation in instructional quality and conceptual accuracy. Effective professional development should be directly connected to the content being taught, involve active teacher learning, be sustained over time, and provide opportunities for teachers to design, test, and reflect on instructional practices.

Desimone and Garet (2015) identified content focus, active learning, coherence, duration, and collective participation as important characteristics of effective professional development. Kennedy (2016) likewise emphasised that professional development improves teaching when it addresses both instructional strategies and the underlying problems of practice. Sims and Fletcher-Wood (2021) further argued that professional learning should enable teachers to connect new knowledge with actual classroom contexts.

Collaboration between science teachers and Islamic Education teachers is also necessary. Science teachers can explain materials, mechanisms, measurements, processes, and the limitations of evidence, whereas Islamic Education teachers can strengthen the normative foundation and principles of halal. Such collaboration can prevent two problematic tendencies: presenting religious messages without scientific grounding and conducting scientific analysis that extends beyond its legitimate authority.

In the context of food safety, communication should also involve dialogue, risk understanding, and active participation rather than one-way transmission of knowledge. Kasza et al. (2022) showed that effective food-safety communication increasingly depends on interactive approaches that consider how individuals interpret risk information. This principle is relevant to halal-related science learning because students need opportunities to ask questions, compare perspectives, and evaluate the consequences of incomplete information.

Overall, the findings suggest that halal concepts have the potential to serve as relevant scientific and socioscientific contexts in science education. However, this potential can be developed systematically only through the careful selection of substantively related topics, explicit clarification of the boundary between scientific evidence and formal halal decisions, the development of appropriate instructional resources, and the strengthening of teacher competence and interdisciplinary collaboration. The present study did not demonstrate improvements in students' scientific literacy or decision-making ability. These outcomes should therefore be examined in future studies through classroom observation, instructional intervention, and direct assessment of student learning.

CONCLUSION

This study examined opportunities for integrating halal concepts into the science curriculum and teacher-reported practices at an Islamic junior and senior high school. The findings indicate that halal concepts can be meaningfully connected with science when integration is based on clear conceptual relationships rather than added as a moral message. The strongest links were found in topics concerning material sources, food and nutrition, the digestive system, food additives, product composition, microorganisms, fermentation, biotechnology, health, and production processes. Teachers identified entry points in Chemistry and Physics, including acids and bases, solutions, colloids, carbon compounds, quantities, measurement, and product observation, confirming the interdisciplinary potential of halal-related learning.

The strength of integration varied across topics. Connections involving food, additives, microorganisms, and biotechnology were more direct, whereas those involving energy, electricity, magnetism, and production technology were more contextual and required pedagogical justification. Reported practices included the use of halal and non-halal examples, label and composition analysis, product observation, and practical activities such as pH testing. These practices suggest a shift toward contextual and inquiry-oriented learning, but they do not yet demonstrate systematic engagement with evidence evaluation, uncertainty, argumentation, or socioscientific decision-making.

A key conclusion concerns the boundary between scientific analysis and formal halal determination. Scientific measurements and laboratory tests can provide information about composition, properties, safety, and processing conditions, but they cannot independently establish halal status. Formal determination requires ingredient traceability, process documentation, equipment assessment, and verification by authorised institutions.

Implementation remains dependent on teachers' knowledge, creativity, collaboration, and access to resources. Because the evidence was limited to curriculum mapping and written teacher responses, the findings represent curricular opportunities and teacher-reported practices rather than observed implementation or student outcomes. Overall, halal concepts offer a promising basis for interdisciplinary and socioscientific science learning, provided that integration is conceptually accurate, pedagogically structured, evidence-based, and institutionally supported.

RECOMMENDATION

Schools should develop structured instructional resources that align halal-related contexts with specific science learning outcomes, scientific concepts, activities, and assessment criteria. Priority should be given to topics with direct substantive relationships to halal, while topics with indirect connections should be used selectively. Professional development should strengthen teachers' understanding of halal, *tayyib*, ingredient sources, production processes, scientific evidence, and the limits of laboratory analysis. Collaboration among integrated-science, Biology, Chemistry, Physics, and Islamic Education teachers is also recommended to ensure that scientific explanations and religious principles are presented accurately and coherently. Future studies should include classroom observations, student interviews, learning artefacts, and direct assessments of scientific literacy, argumentation, and decision-making. Research involving additional schools and educational contexts would also help determine the transferability of the findings and support the development of empirically tested halal-integrated science-learning models.

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AUTHOR CONTRIBUTIONS STATEMENT

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Salman Al Farisi	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
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Akhmad Sukri	✓		✓		✓		✓			✓	✓		✓	

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

This research involving human participants complied with all relevant national regulations and institutional policies, adhered to the principles of the Declaration of Helsinki, obtained written informed consent from all participants, and was approved by Mandalika University of Education.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy considerations of research participants.

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