

# Geographisches Forschendes Lernen zu regionalen Implikationen des Klimawandels im wissenschaftspropädeutischen Seminar der gymnasialen Oberstufe

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regionalen Implikationen des  
Klimawandels im  
wissenschaftspropädeutischen Seminar  
der gymnasialen Oberstufe.**

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## **Vorwort und Danksagung**

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## **Abstract**

This cumulative dissertation examines how inquiry-based learning (IBL) can be used in geography to address the complex challenges of climate change education (CCE) in upper secondary schools. These challenges go beyond the mere transfer of knowledge and must also promote skills in areas such as scientific work, judgment formation, and responsible action.

As part of the interdisciplinary research network BAYSICS, a design-based research project was carried out to develop, test, and optimize a geographical science-propaedeutic seminar (“W-Seminar”) on the regional implications of climate change for upper secondary school students based on the inquiry-based learning approach. The three individual studies address different dimensions: (1) a structured literature analysis that highlights the particular potential of IBL for CCE, (2) the iterative development and empirical evaluation of a learning environment in two research cycles with more than 400 students and 30 teachers, and (3) an in-depth analysis of the particularly challenging phase of question formulation and research planning.

The results show that inquiry-based learning is particularly well suited to promoting complex scientific, methodological, social, and epistemic skills. At the same time, key challenges were identified, such as learners' lack of prior experience and the high demands placed on teachers' professionalization. On this basis, a practical learning environment and a theoretically sound catalog of design principles were developed to support the sustainable implementation of inquiry-based learning in a school context.

The dissertation thus makes both an empirical-theoretical contribution to the didactics of inquiry-based learning and a practical contribution to the further development of inquiry-based learning and CCE in schools. It opens up opportunities for follow-up studies, particularly quantitative ones, as well as for a stronger anchoring of inquiry-based learning in curricula and teacher training.

## **Zusammenfassung**

Diese kumulative Dissertation untersucht, wie forschendes Lernen (Inquiry-Based Learning, IBL) im Fach Geographie genutzt werden kann, um die komplexen Herausforderungen der Climate Change Education (CCE) in der gymnasialen Oberstufe zu adressieren. Diese gehen über reine Wissensvermittlung hinaus und müssen u.a. Kompetenzen in den Bereichen wissenschaftliches Arbeiten, Urteilsbildung und verantwortungsvolles Handeln fördern.

Im Rahmen des interdisziplinären Forschungsverbunds BAYSICS wurde ein Design-Based-Research-Projekt durchgeführt, das ein geographisches wissenschaftspropädeutisches Seminar („W-Seminar“) zum Klimawandel in der eigenen Region für die gymnasiale Oberstufe nach dem Ansatz des forschenden Lernens entwickelte, erprobte und optimierte. Die drei Einzelstudien adressieren dabei unterschiedliche Dimensionen: (1) eine strukturierte Literaturanalyse, die die besonderen Potenziale von IBL für die CCE herausarbeitet, (2) die iterative Entwicklung und empirische Evaluation einer Lernumgebung in zwei Forschungszyklen mit mehr als 400 Schüler:innen und 30 Lehrkräften sowie (3) eine vertiefte Analyse der besonders anspruchsvollen Phase der Fragefindung und Forschungsplanung.

Die Ergebnisse zeigen, dass forschendes Lernen besonders geeignet ist, um vielfältige wissenschaftliche, methodische, soziale und epistemische Kompetenzen zu fördern. Zugleich wurden zentrale Herausforderungen identifiziert, etwa mangelnde Vorerfahrungen der Lernenden oder hohe Anforderungen an die Professionalisierung von Lehrkräften. Auf dieser Basis wurden eine praxistaugliche Lernumgebung sowie ein theoretisch fundierter Katalog von Designprinzipien entwickelt, die eine nachhaltige Implementierung von forschendem Lernen im schulischen Kontext unterstützen.

Die Dissertation leistet damit sowohl einen empirisch-theoretischen Beitrag zur Didaktik des forschenden Lernens als auch einen praktischen Beitrag zur Weiterentwicklung des forschenden Lernens sowie der CCE in Schulen. Sie eröffnet Anschlussmöglichkeiten für insbesondere quantitative Folgestudien sowie eine stärkere Verankerung von forschendem Lernen in Curricula und Lehrkräftebildung.

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# 1 Einführung

Der Klimawandel stellt eines der zentralen Menschheitsprobleme des 21. Jahrhunderts dar. Seine Ursachen und Folgen sind weder auf einzelne Regionen noch auf bestimmte gesellschaftliche Gruppen begrenzt, sondern wirken auf unterschiedlichen Maßstabsebenen und mit hoher Interdependenz zwischen ökologischen, ökonomischen und sozialen Systemen (IPCC, 2023). Charakteristisch ist, dass der Klimawandel nicht als klar abgrenzbares Umweltproblem erscheint, sondern als sogenanntes „wicked problem“ (Levin et al., 2012), das durch Komplexität, Unsicherheiten und Zielkonflikte geprägt ist. Damit wird er nicht nur zu einem Gegenstand natur- und sozialwissenschaftlicher Forschung, sondern ebenso zu einer gesellschaftlichen und kulturellen Herausforderung ersten Ranges.

Für Individuen zeigt sich der Klimawandel zudem nicht allein als fernes globales Phänomen, sondern wirkt zunehmend in alltägliche Lebenswelten hinein – sei es durch spürbare Veränderungen in der physischen Umwelt, durch mediale Diskurse oder durch politische Aushandlungsprozesse, die den Alltag strukturieren. Forschungsergebnisse verdeutlichen, dass Menschen den Klimawandel in hohem Maße durch subjektive Wahrnehmungen, kulturelle Deutungsmuster und soziale Konstruktionen verarbeiten (Stoll-Kleemann et al., 2001; O’Neill & Nicholson-Cole, 2009). Dies macht ihn zu einem Thema, das sowohl wissenschaftlich fundiertes Orientierungswissen als auch alltagsweltlich anschlussfähige Kommunikationsformen erfordert.

Aus fachlicher Sicht vereint der Klimawandel Perspektiven zahlreicher Disziplinen: So liefern etwa Atmosphärenphysik, Biologie, Ökonomie, Soziologie und Politikwissenschaft jeweils spezifische Zugänge. Besonders der Geographie kommt hier eine Schlüsselrolle zu. Aufgrund ihres integrativen Charakters ist sie prädestiniert, natur- und sozialwissenschaftliche Dimensionen zusammenzuführen, systemische Zusammenhänge in Mensch-Umwelt-Beziehungen sichtbar zu machen und diese in räumlicher Perspektive zu analysieren (Wardenga, 2002; Fu et al., 2022). Der Klimawandel wird damit zu einem exemplarischen Gegenstand, an dem auch im schulischen Kontext die fachspezifische Stärke der Geographie als Brückenfach erkennbar wird: Sie verknüpft globale Prozesse mit regionalen

Ausprägungen und eröffnet so Lernenden konkrete, raumbezogene Zugänge zu einem hochkomplexen Thema.

### 1.1 Relevanz von Bildung zum Klimawandel (Climate Change Education)

Angesichts der beschriebenen gesellschaftlichen und fachlichen Bedeutung des Klimawandels kommt der Bildung eine zentrale Funktion zu. Bildung zu Klimawandelthemen – häufig unter dem Begriff Climate Change Education (CCE) gefasst – verfolgt das Ziel, Lernende dazu zu befähigen, die Komplexität des Phänomens zu verstehen, fundierte Urteile zu bilden und reflektiert sowie verantwortungsbewusst zu handeln (UNESCO, 2015). Unter dem Konstrukt der „Climate Literacy“ lässt sich eine solche Klimakompetenz fassen als (1) Wissen über Klimawissenschaft in ihren inhaltlichen, prozeduralen und epistemischen Dimensionen, (2) Kompetenzen zur Informationsrecherche, -bewertung und -kommunikation sowie (3) Haltungen, die zu eigenem Engagement bei der Entwicklung und Umsetzung von Anpassungs- und Minderungsstrategien führen (Azevedo & Marques, 2017). Dabei geht es nicht allein um die Vermittlung naturwissenschaftlicher Inhalte. Insbesondere die ersten beiden Dimensionen verdeutlichen, dass Climate Literacy als spezifische Anwendungskonstellation von „Scientific Literacy“ verstanden werden kann. Diese ist durch die Fähigkeit charakterisiert, Phänomene wissenschaftlich zu erklären, wissenschaftliche Untersuchungen zu evaluieren und zu gestalten sowie Daten und Evidenz kritisch zu interpretieren (OECD, 2017). CCE muss daher auch wissenschafts- und forschungsbezogene Kompetenzen integrieren. Darüber hinaus reicht vor allem die dritte genannte Dimension der Climate Literacy in die Gestaltungskompetenzen der Bildung für nachhaltige Entwicklung hinein, welche auf die Fähigkeit zielen, komplexe Probleme systemisch zu erfassen, Handlungsoptionen zu entwickeln und transformativ wirksam zu werden (de Haan, 2008). Zentral ist zudem die Förderung von Fähigkeiten, die den Umgang mit Unsicherheiten und Zielkonflikten ermöglichen (Wiek et al., 2011; Monroe et al., 2019). In diesen Kompetenzbereichen wirkungsvoll umgesetzte Climate Change Education kann zugleich auch einen wertvollen Beitrag zur erfolgreichen Teilhabe und Mitgestaltung Heranwachsender an den Prozessen und Herausforderungen des 21. Jahrhunderts leisten, denn alle genannten Kompetenzbereiche weisen zudem teils

starke Überschneidungen mit den sogenannten „21st Century Skills“ auf: Zu diesen zählen etwa kritisches Denken und Problemlösen, Kreativität und Innovationsfähigkeit, Kooperation, oder Kompetenzen für Informationsgewinnung und Medienrezeption (Trilling & Fadel, 2009; Partnership for 21st Century Learning, 2019).

## 1.2 Stand der Forschung zu Climate Change Education in der geographischen Bildung

Vor dem Hintergrund dieser Einordnung stellt sich die Frage, welche spezifischen Erkenntnisse die aktuelle Forschung zu Climate Change Education – insbesondere im geographischen Bildungskontext – bereithält. Im Folgenden werden daher in der Literatur beschriebene zentrale Herausforderungen, wirksame Ansätze bzw. Prinzipien sowie die besonderen Potentiale der geographischen Bildung überblicksweise zusammengefasst.

### 1.2.1 Herausforderungen

Die Forschung verweist auf eine Reihe zentraler Herausforderungen im Kontext von CCE. Besonders bedeutsam sind dabei:

- Fehlvorstellungen über den Klimawandel, etwa die Verwechslung von Treibhauseffekt und Ozonloch (Felzmann, 2018; Reinfried & Tempelmann, 2014; Schuler, 2011).
- Kontroverse Darstellungen in den Medien sowie Desinformation und „Fake News“, die das Vertrauen in wissenschaftliche Befunde unterminieren (Höttecke & Allchin, 2020; Sharon & Baram-Tsabari, 2020).
- Unzureichendes Verständnis wissenschaftlicher Erkenntnisgewinnung, insbesondere auf prozeduraler und epistemologischer Ebene, was dazu führt, dass wissenschaftliche Aussagen entweder unkritisch übernommen oder pauschal abgelehnt werden (Höttecke & Allchin, 2020; Sharon & Baram-Tsabari, 2020).
- Faktische und ethische Komplexität des Themas, die Lehrkräfte wie Lernende gleichermaßen überfordern kann (Ohl, 2013; Meyer et al., 2018).
- Emotionale Reaktionen wie Angst und Machtlosigkeit, die durch die Tragweite der Problematik ausgelöst werden (Hickman et al., 2021).

- Limitierte Partizipationsmöglichkeiten von Jugendlichen an Klimathemen (Hwang, 2025).
- Eine Kluft zwischen Wissen und Handeln, die selbst bei hohem Problembewusstsein zu geringer Handlungsbereitschaft führt (Renn, 2018).
- Die wahrgenommene „psychologische Distanz“ zu den Prozessen und Folgen des Klimawandels, die das Thema als zeitlich und räumlich fern erscheinen lässt (Chiari et al., 2016; Fiene, 2014; Keller et al., 2022).

Diese Befunde verdeutlichen, dass Klimawandelbildung mit komplexen kognitiven und emotionalen Barrieren konfrontiert ist, die in Lehr-Lern-Arrangements gezielt adressiert werden müssen.

### **1.2.2 Wirksame Ansätze und Prinzipien der Climate Change Education**

Als Reaktion auf diese Herausforderungen hebt die Forschung bestimmte Ansätze hervor, die sich als besonders wirksam erweisen:

- Partizipative und handlungsorientierte Lernformen, die Lernende aktiv in Problembearbeitungen einbeziehen und Gestaltungskompetenz fördern (z.B. Feierabend & Eilks, 2011; Monroe et al., 2017).
- Lokal verankerte Lernumgebungen, die globale Dynamiken in Bezug zur eigenen Lebenswelt setzen und damit die „psychological distance“ verringern (z.B. McDonald et al., 2015; Duke & Holt, 2024).
- Systemisches Denken und multiperspektivische Analysen, die die Vielschichtigkeit des Themas abbilden und disziplinübergreifendes Verstehen fördern (z.B. Wiek et al., 2011; Frey et al., 2025).
- Explizite Auseinandersetzung mit wissenschaftlicher Erkenntnisproduktion, um epistemologisches Verständnis zu fördern und Wissenschaftsskepsis zu begegnen (z.B. Höttecke & Allchin, 2020; Holthuis et al., 2014).
- Forschendes Lernen / Inquiry-Based Learning, das Lernende befähigt, eigene Fragestellungen zu entwickeln, Daten zu erheben und wissenschaftspropädeutische Verfahren anzuwenden (z.B. Brumann et al., 2022b).

Diese Ansätze stehen exemplarisch für eine didaktische Entwicklung, die den Klimawandel nicht nur als Wissens-, sondern vor allem als Lern- und Handlungsfeld begreift.

### **1.2.3 Potenziale der geographischen Bildung**

Vor dem Hintergrund der skizzierten Herausforderungen lassen sich spezifische Beitragspotenziale der Geographie für die Klimawandelbildung herausarbeiten, wie sie in der geographiedidaktischen Forschung wiederholt betont werden (vgl. u.a. Ohl & Sprenger, im Druck):

- **Raumbezogene Perspektive:** Der Geographieunterricht eröffnet die Möglichkeit, globale Dynamiken auf lokale Kontexte zu beziehen und umgekehrt lokale Beobachtungen in globale Zusammenhänge einzuordnen. Zudem betrachtet die Geographie Phänomene und Prozesse auf unterschiedlichen zeitlichen Ebenen, sodass etwa gegenwärtige Erscheinungen des Klimawandels in langfristige Trends eingeordnet werden können. Dadurch kann die in der Forschung vielfach beschriebene Herausforderung einer empfundenen zeitlichen und räumlichen Distanz (vgl. oben) gezielt überwunden werden (Fögele, 2016).
- **Systemisches Denken:** Geographische Bildung fördert die Analyse komplexer Mensch-Umwelt-Systeme und macht Wechselwirkungen zwischen natürlichen und gesellschaftlichen Prozessen transparent. Die zusammenhängende Betrachtung von räumlich bedeutsamen Strukturen, Funktionen und Prozessen sowie das bereits erwähnte Einbeziehen verschiedener räumlicher und zeitlicher Maßstabebenen hilft, Komplexität zu strukturieren und fachliche wie ethische Vielschichtigkeit didaktisch zu erschließen (Deutsche Gesellschaft für Geographie e. V., 2020; Fögele, 2016; Wardenga, 2002).
- **Perspektivenvielfalt und Interdisziplinarität:** Als Integrationsfach verbindet Geographie naturwissenschaftliche, sozialwissenschaftliche und kulturwissenschaftliche Perspektiven. Damit schafft sie einen Rahmen für multiperspektivische Urteilsbildung und eröffnet den Lernenden Möglichkeiten, auch die ethische und politische Dimension des Klimawandels in ihre Überlegungen einzubeziehen (Fu et al., 2022).

- Geographische Methoden: Die Geographie verfügt über ein breites Spektrum an raum- und maßstabsbezogenen (z.B. Exkursionen, Kartierung, Geographische Informationssysteme, digitale Geomedien), systemischen und modellierenden (z.B. Wirkungsgefüge, Concept Maps, Szenarienarbeit und Modellierungen), handlungs- und entscheidungsorientierten (z.B. Planspiele / Rollenspiele, Dilemmadiskussionen, Debatten), visualisierungs- und medienkritischen (z.B. Analyse von Klimadiagrammen, Satellitenbildern, Infografiken, Medientexten) sowie narrativen / reflexiven (z.B. Storytelling) Zugängen, um klimawandelbezogene Fragestellungen evidenzbasiert zu analysieren. Diese Werkzeuge fördern wichtige Kompetenzen in unterschiedlichen Bereichen – wie etwa Fachwissen, Erkenntnisgewinnung, Beurteilen/Bewerten, Kommunikation oder Handlung –, die als zentral für den Aufbau einer „Climate Literacy“ (siehe Kap. 1.1) betrachtet werden können (Yli-Panula et al., 2020; Meadows, 2020).
- Handlungs- und Erfahrungsorientierung: Authentische Lernformate wie Exkursionen, Planspiele, Fallstudien oder partizipative Projekte ermöglichen es, klimabezogene Fragestellungen konkret zu erleben und eigene Handlungsspielräume zu erkunden. Damit kann der im Forschungskontext wiederholt beobachteten Kluft zwischen Wissen und Handeln (vgl. oben) entgegengewirkt werden. Gleichzeitig können solche Zugänge eine Antwort auf Gefühle von Machtlosigkeit und Angst bieten, die Jugendliche im Kontext des Klimawandels häufig äußern (Chiari et al., 2016).
- Umgang mit Fehlvorstellungen und Medienkritik: Die Arbeit mit den Präkonzepten Lernender hat in der Geographiedidaktik einen hohen Stellenwert (Reinfried, 2007). Dadurch können hartnäckige Fehlvorstellungen – etwa die Verwechslung von Treibhauseffekt und Ozonloch (vgl. oben) – gezielt aufgegriffen werden. Ergänzt wird dies durch Medien- und Bildkritik, die etwa Desinformation und Bildrhetorik thematisiert (Nöthen, 2018) und damit einen Beitrag zur Förderung von Visual Literacy und zur Auseinandersetzung mit „Fake News“ im Klimakontext leistet.

- Forschendes Lernen: Besonders hervorzuheben ist die Anschlussfähigkeit der Geographie an forschendes Lernen (Inquiry-based Learning, IBL). Durch authentische, regional und lebensweltlich verankerte Forschungsaktivitäten zu offenen Fragestellungen lassen sich wissenschaftspropädeutische Lernprozesse anbahnen. Wie die Literatur zu forschendem Lernen zeigt, können damit nahezu alle zuvor genannten Herausforderungen adressiert werden (vgl. etwa Brumann et al., 2019; 2022b). Damit stellt es einen besonders vielversprechenden Ansatz dar, um die zentralen Herausforderungen der Klimabildung kohärent zu bearbeiten.

Insgesamt zeigt sich: Der Geographieunterricht hält eine Vielzahl an Zugängen bereit, die zentrale Herausforderungen von Climate Change Education adressieren. Forschendes Lernen kann dabei eine Schlüsselstellung einnehmen, die in den folgenden Kapiteln eingehender diskutiert wird.

## **2 Forschendes Lernen**

Bildungspraktiken, die Lernende aktiv in Forschungsaktivitäten und wissenschaftliches Denken einbinden, haben eine lange Tradition. Entsprechende Ansätze lassen sich mindestens bis in die 1960er Jahre zurückverfolgen und wurden seitdem in die Bildungsstandards und Lehrpläne vieler Länder eingebunden (Furtak et al., 2012; Crawford, 2014; Vorholzer & Aufschnaiter, 2019). Zu einer besonders großen Popularität, vor allem mit einem Fokus auf den Kontext Schule, gelangten solche Lernformen spätestens seit den 1990er Jahren mit der Formulierung der „National Science Education Standards“ in den USA (Vorholzer & Aufschnaiter, 2019; Apedoe et al., 2006; Chinn & Malhotra, 2002; Furtak et al., 2012; Lazonder & Harmsen, 2016; Costes-Onishi et al., 2020; Levy et al., 2013; Crawford, 2014; National Research Council, 1996; 2000; 2012).

Während im internationalen Diskurs bis heute eine Vielzahl unterschiedlicher Begriffe zur Beschreibung solcher Ansätze herangezogen wird – so zum Beispiel „Inquiry-based instruction“, „Inquiry learning“, „Inquiry Teaching“ oder „Research-based learning“ (zur Inkonsistenz der Begrifflichkeiten vgl. etwa (Furtak et al., 2021; Lazonder & Harmsen, 2016; Scott & Friesen, 2013) –, hat sich als Sammelbegriff die Bezeichnung „Inquiry-based learning“ (IBL) herausgebildet (Spronken-Smith & Kingham, 2009). Im deutschsprachigen Raum hat sich für die

Idee eines „Lernens durch Forschung“ der Begriff des „Forschenden Lernens“ durchgesetzt. Das Konzept wurde dabei maßgeblich im Rahmen der Bundesassistentenkonferenz 1970 geprägt und seitdem vor allem als hochschuldidaktisches Prinzip diskutiert und erforscht (vgl. etwa BAK, 2009; Huber, 1970; 2009; 2017; Reinmann, 2011; 2015; 2019; Sonntag et al., 2016).

Wenngleich aus dieser Tradition heraus in hochschuldidaktischen Publikationen (z.B. Huber, 2014) „Forschendes Lernen“ oftmals sehr wissenschaftsnah definiert wird, hält der Begriff bereits seit den 2000er Jahren auch Einzug in den deutschsprachigen Schulkontext und findet dort in ebenso vielfältiger Ausprägung wie auf internationaler Ebene immer breitere Anwendung (siehe z.B. Wilhelmi, 2000; Maisenbacher, 2000; Röhl & Eberth, 2020; Hofer & Puddu, 2020; Mayer & Ziemek, 2006; Knörzer et al., 2019). Vor diesem Hintergrund werden im Rahmen dieser Arbeit „Inquiry-based learning“ und „Forschendes Lernen“ synonym als englischer bzw. deutscher Sammelbegriff für eine ganze Reihe an im Kern ähnlichen Lernformen verwendet. Prototypisch zusammengefasst meint Forschendes Lernen bzw. IBL solche Lernformen, die auf die Befähigung von Schüler:innen abzielen, wissenschaftliche Fragen zu stellen, selbstständige Untersuchungen durchzuführen und ihre Ergebnisse mit fundierten Argumenten zu begründen, wobei sie die Haltungen, Methoden und Vorgehensweisen professioneller Wissenschaftler:innen aufgreifen (Brumann & Ohl, 2019; Lazonder & Harmsen, 2016; Messner, 2009; Pedaste et al., 2015; Tomčíková, 2020).

Wie Abbildung 1 zeigt, lassen sich Formate Forschenden Lernens anhand unterschiedlicher Gesichtspunkte in einem Spektrum weiter ausdifferenzieren. Dieses reicht von didaktisch stark reduzierten Ansätzen, die sich deutlich von authentischer Forschung unterscheiden – z.B. stark angeleitete Experimente im Rahmen einer einzelnen Unterrichtseinheit – bis hin zu umfassenden Projekten, die professioneller wissenschaftlicher Forschung in vielen Merkmalen sehr nahekommen.

## Spektrum forschenden Lernens

schon im Rahmen einer Unterrichtseinheit oder Unterrichtsphase realisierbar	<b>Dauer des unterrichtlichen Vorhabens</b>	nur längerfristig denkbar, z.B. im Rahmen von Projekten
gering; distinkte „Wissenseinheiten“ erlernbar	<b>Umfang des Stoffs</b>	hoch; komplexer Stoff, der sukzessive durchdrungen wird
starker Fokus auf <i>entweder</i> rein physisch-geographische / naturwissenschaftliche Fragestellung <i>oder</i> humangeographische / gesellschafts- bzw. geisteswissenschaftliche Fragestellung	<b>Inhaltliche Ausrichtung</b>	integrative Zugänge unter Berücksichtigung gesellschafts-, geistes- und naturwissenschaftlichen Perspektiven
methodischer Einzelfokus (z.B. Experiment, Zählung, Befragung)	<b>Methodisches Repertoire</b>	Ermöglichung multipler Methoden aus Gesellschafts-/Geistes-/Naturwissenschaften
gering; zumeist Fokussierung auf einzelne inhaltliche und/oder methodische Facetten (z.B. bestimmte wissenschaftliche Konzepte oder fachspezifische Arbeitstechniken)	<b>Wissenschaftsorientierung</b>	starke Orientierung an inhaltlichen und methodischen Strukturen sowie gesellschaftlichen Bezügen der jeweiligen Wissenschaftsdisziplin; Nachdenken und Reflexion über Wissenschaft; Durchlaufen eines ganzen Forschungszyklus
für die Lernenden potentiell neue Erkenntnisse	<b>Anspruch an die Erkenntnisse</b>	Erkenntnisse, die über die individuellen Lernprozesse hinaus für Dritte von Bedeutung und ggf. neu sind
nicht zwangsläufig gegeben; Lerninhalte/-ziele sind zwar potentiell neu, müssen aber nicht den Ausgangspunkt der individuellen Lernaktivitäten darstellen	<b>Epistemische Aktivität (i.S.v. individuellem Erkenntnisstreben)</b>	hoch; Neugier und eigene Fragen der SuS als Ausgangspunkt des Lernprozesses, intrinsisch motivierte Suche nach Antworten
gering; Orientierung am Rahmen von üblichen Einzel- oder Doppelstunden	<b>Organisatorische Offenheit</b>	hoch; Öffnung des üblichen Unterrichtsrahmens, z.B. zugunsten von Feldforschungsphasen, Projekten, Schreibwerkstätten,...
gering; Behandlung ganz konkreter, von der Lehrkraft vorgegebener Inhalte	<b>Inhaltliche Offenheit</b>	hoch; breiter und lebensweltorientierter Themenkomplex, genaue Inhalte durch die Lehrkraft nicht vorab determiniert
gering; stark strukturiertes, angeleitetes Vorgehen; Forschungsfrage i.d.R. vorgegeben	<b>Eigenständigkeit der Lernenden</b>	hoch; größtenteils selbständige Entwicklung von Forschungsfragen und Gestaltung des Erhebungs- und Auswertungsprozesses

**Abbildung 1: Spektrum unterschiedlicher Formate forschenden Lernens.**

Quelle: Brumann & Ohl, 2019, S. 102f.

Gerade für den Kontext Schule lässt sich in der Fachliteratur ein Spannungsverhältnis feststellen: Hinsichtlich wissenschaftsbezogener Kompetenzen, die durch Forschendes Lernen – gerade auch in der Climate Change Education – adressiert werden sollen (Lernen durch Wissenschaft statt lediglich über Wissenschaft), fordern viele Autor:innen eine möglichst ausgeprägte Orientierung an authentischer Wissenschaft (siehe etwa: Chinn & Malhotra, 2002; Willison & O'Regan, 2007; Spronken-Smith & Walker, 2010; Levy et al., 2013; Bevins & Price, 2016; Wiemer, 2017). Zugleich zeigt aber eine breite empirische Forschungsbasis, dass Forschendes Lernen vor allem in der Schule auf umfassende didaktische Unterstützung und Vereinfachung angewiesen ist, um erfolgreiche Lernprozesse zu ermöglichen (z.B.: Crawford, 2014; Kirschner et al., 2006; Furtak et al., 2012; Lazonder & Harmsen, 2016; Rönnebeck et al., 2016).

Diese beiden Pole schließen sich jedoch nicht gegenseitig aus, denn im Sinne eines kumulativen Kompetenzerwerbs bedeutet Forschendes Lernen „auf unterschiedlichen Altersstufen Verschiedenes“ (Messner, 2009). Folgerichtig stellen entsprechende Modelle (siehe beispielsweise Banchi & Bell, 2008; Bevins & Price, 2016; National Research Council, 2000; Schneider & Wildt, 2007; Willison & O'Regan, 2007) das Spektrum an Lernformaten in der Regel als aufeinanderfolgende Stufen in einem Entwicklungsverlauf dar: In frühen Stadien der wissenschaftlichen Bildung beschränkt sich das Forschen oft auf von der Lehrkraft vorgegebene Fragen, Daten und Ergebnisinterpretationen sowie auf vorab festgelegte Lernschritte und -verfahren (vgl. Banchi & Bell, 2008; Schneider & Wildt, 2007; Willison & O'Regan, 2007). Mit der fortschreitenden Entwicklung der forschungsbezogenen Kompetenzen der Schüler:innen entwickeln sich die angewandten Ansätze Forschenden Lernens zu offeneren und komplexeren Formen. Auf der höchsten Komplexitätsstufe umfasst Forschendes Lernen idealerweise von den Schüler:innen selbst formulierte Forschungsfragen, selbstgesteuerte Datenerhebung und -analyse mittels von den Schüler:innen entwickelten methodischen Ansätzen sowie die eigenständige Synthese und Interpretation der Forschungsergebnisse (siehe beispielsweise Banchi & Bell, 2008; Schneider & Wildt, 2007; Willison & O'Regan, 2007). Abbildung 2 zeigt diese Entwicklungsstufen exemplarisch anhand des „Research Skill Development Framework“ von Willison & O'Regan (2007; 2006/2012) auf.

# Research Skill Development Framework

www.rsd.edu.au

A conceptual framework for the explicit, coherent, incremental and spiralling development of students' research skills

		Extent of Students' Autonomy				
		Level 1 (Prescribed Research)	Level 2 (Bounded Research)	Level 3 (Scaffolded Research)	Level 4 (Student-initiated Research)	Level 5 (Open Research)
<p>What characterises the difference between 'search and research'? More searching and more data generation is just a 'bigsearch'! Research is when students...</p> <p><b>RSD</b></p>	Curious	Highly structured directions and modelling from educator prompt student research	Boundaries set by and limited directions from educator channel student research	Scaffolds placed by educator shape student independent research	Students initiate the research and this is guided by the educator	Students research within self-determined guidelines that are in accord with discipline or context.
	a. Embark & Clarify	Respond to questions/tasks explicitly from a closed inquiry. Use a provided structured approach to clarify questions, terms, requirements and expectations.	Respond to questions/tasks required by and implicit in a closed inquiry. Choose from several provided structures to clarify questions, terms, requirements and expectations.	Respond to questions/tasks generated from a closed inquiry. Choose from a range of provided structures or approaches to clarify questions, terms, requirements and expectations.	*Generate questions/aims/hypotheses framed within structured guidelines*.	*Generate questions/aims/hypotheses based on experience, expertise and literature*.
	b. Find & Generate	Find and record required information or data using a prescribed methodology from a prescribed source in which the information/data is clearly evident.	Collect and record required information/data using a prescribed methodology from prescribed sources in which the information/data is not clearly evident.	Collect and record required information/data from self-selected sources using one of several prescribed methodologies.	Collect and record self-determined information/data from self-selected sources, choosing an appropriate methodology based on structured guidelines.	Collect and record self-determined information/data from self-selected sources, choosing or devising an appropriate methodology with self-structured guidelines.
	c. Evaluate & Reflect	Determine and critique the degree of credibility of selected sources and of data generated, and reflect on the research processes used.	Evaluate information/data and reflect on the inquiry process using given criteria.	Evaluate information/data and inquiry process using criteria related to the aims of the inquiry. Reflect insightfully to improve own processes used.	Evaluate information/data and the inquiry process comprehensively using self-determined criteria developed within structured guidelines. Reflect insightfully to refine others' processes.	Evaluate information/data and inquiry process rigorously using self-generated criteria based on experience, expertise and the literature. Reflect insightfully to renew others' processes.
	d. Organise & Manage	Organise information and data to reveal patterns and themes, and manage teams and research processes.	Organise information/data using a choice of given structures. Manage a process which has alternative pathways.	Organise information/data using recommended structures. Manage self-determined processes with multiple possible pathways.	Organise information/data using student-determined structures, and manage the processes, within the parameters set by the guidelines.	Organise information/data using student-determined structures and management of processes.
	e. Analyse & Synthesise	Analyse information/data critically and synthesise new knowledge to produce coherent individual/team understandings.	Analyse and synthesise information/data to reorganize existing knowledge in standard formats. *Ask relevant, researchable questions emerging from the research*.	Analyse and synthesise information/data to construct emergent knowledge. *Ask rigorous, researchable questions based on new understandings*.	Analyse and create information/data to fill knowledge gaps stated by others.	Analyse and create information/data to fill student-identified gaps or extend knowledge.
f. Communicate and Apply	Write, present and perform the processes, understandings and applications of the research, and respond to feedback, accounting for ethical, social and cultural (ESC) issues.	Use some discipline-specific language and prescribed genre to demonstrate understanding for a specified audience. Apply to a similar context the knowledge developed. Follow prompts on ESC issues.	Use discipline-specific language and genres to demonstrate scholarly understanding for a specified audience. Apply the knowledge developed to diverse contexts. Specify ESC issues in initiating, conducting and communicating.	Use discipline-specific language and genres to address gaps of a self-selected audience. Apply innovatively the knowledge developed to a different context. Probe and specify ESC issues in each relevant context.	Use appropriate language and genre to extend the knowledge of a range of audiences. Apply innovatively the knowledge developed to multiple contexts. Probe and specify ESC issues that emerge broadly.	
<p>Research Skill Development (RSD), a conceptual framework for Primary school to PhD, developed by John Willison and Kerry O'Regan © October, 2006/November, 2012. Facets based on: ANZIL (2004) Standards &amp; Bloom's et al (1956) Taxonomy.</p> <p>* Framing researchable questions often requires a high degree of guidance and modelling for students and, initially, may need to be scaffolded as an outcome of the researching process (Facet E, Levels 1-3). After development, more students are able to initiate research (Facet A, Levels 4 &amp; 5). * The perpendicular font reflects the drivers and enablers of research. Framework, resources, learning modules and references available at <a href="http://www.rsd.edu.au">http://www.rsd.edu.au</a>. For info: john.willison@bedalade.edu.au</p>						

Abbildung 2: Das "Research Skill Development Framework"-Modell

Quelle: Willison & O'Regan, 2006/2012.

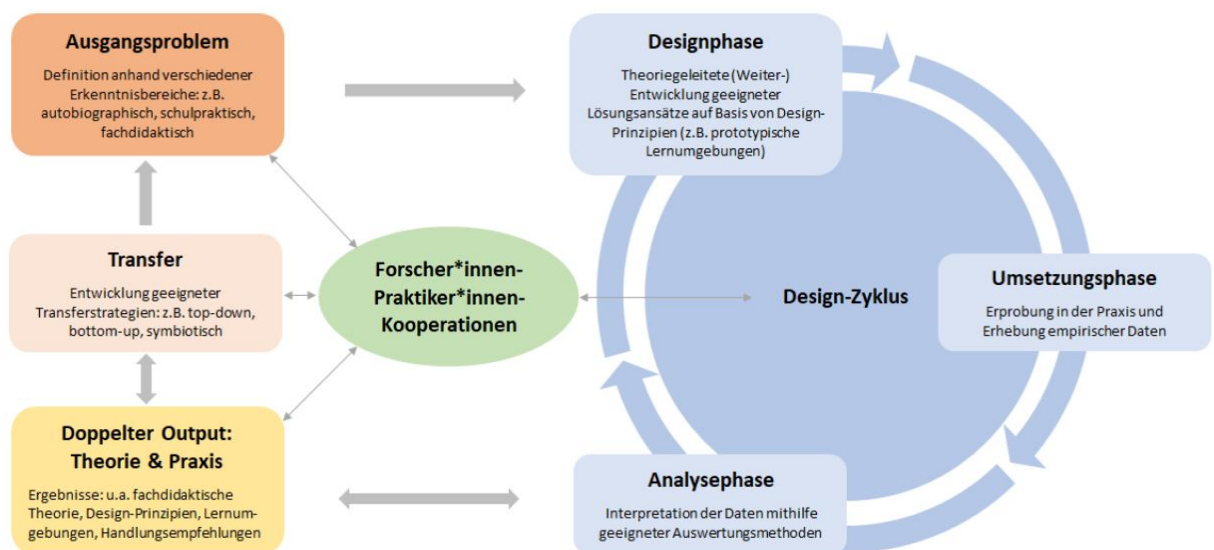
### **3 Operationalisierung Forschenden Lernens für die Climate Change Education in der gymnasialen Oberstufe**

Das Forschungsprojekt, aus dem die vorliegende Dissertation hervorgegangen ist, war eingebettet in den interdisziplinären Forschungsverbund BAYSICS, welcher im Rahmen des Bayerischen Netzwerks für Klimaforschung, bayklif, durch das Bayerische Staatsministerium für Wissenschaft und Kunst gefördert wurde. Ziel von BAYSICS war es, in einem Citizen-Science-Ansatz mit dem Leitbild „Wissen vermitteln – Wahrnehmung fördern – Komplexität kommunizieren“ regionale Implikationen des Klimawandels in Bayern für verschiedene Akteursgruppen (z.B. Erholungssuchende, naturinteressierte Bürger:innen, Schüler:innen) durch eigene Beobachtungen greifbar zu machen (Menzel, 2017). Dafür wurde in enger Kooperation zwischen zehn Teilprojekten aus den Bereichen Klimaforschung, Informatik, Umweltsoziologie und Biologie- sowie Geographiedidaktik eine interaktive Online-Plattform entwickelt, die es Bürgerwissenschaftler:innen erlaubt, ausgewählte Facetten des Klimawandels mithilfe von interaktiven Tools „vor der eigenen Haustür“ zu untersuchen. Das am Lehrstuhl für Didaktik der Geographie an der Universität Augsburg beheimatete und durch den Autor dieser Arbeit maßgeblich bearbeitete Teilprojekt 8 dieses Forschungsverbundes ging dabei der übergeordneten Fragestellung nach, wie wissenschaftsnahes Forschendes Lernen zum Klimawandel in der eigenen Region in wissenschaftspropädeutischen Seminaren der bayerischen gymnasialen Oberstufe („W-Seminare“) gestaltet werden kann, um Schüler:innen als „Citizen Scientists“ zu eigenen Forschungsaktivitäten im Kontext des Klimawandels zu befähigen und ihnen den erfolgreichen Aufbau einer „Scientific Literacy“ bzw. „Climate Literacy“ zu ermöglichen.

#### **3.1 Kurzüberblick über das Forschungsprojekt und Einordnung der Einzelbeiträge**

Als übergeordneter Forschungszugang für das gesamte Projekt wurde der „Design-based Research“-Ansatz (DBR) (Feulner et al., 2021) gewählt, welcher in Abbildung 3 schematisch dargestellt wird. Einem DBR-Projekt liegt charakteristischerweise ein zentrales Theorie-Praxis-Problem zugrunde (Feulner et

al., 2021). Im vorliegenden Fall war dies der offensichtliche Mangel an praxistauglichen Konzeptionen eines umfassenden, wissenschaftsnahen Forschenden Lernens im Schulkontext einerseits sowie die fehlenden theoretischen Grundlagen zur Gestaltung und Anwendung einer solchen Lernumgebung andererseits. Folgerichtig zielen DBR-Projekte immer auch auf einen doppelten Output ab, indem sowohl die Entwicklung einer Praxiskonzeption als auch ein Beitrag zur didaktischen Theoriebildung angestrebt werden (Feulner et al., 2021). Gekennzeichnet ist der Forschungsprozess dabei einerseits durch eine enge Forscher-Praktiker-Kooperation (hier: Forschende und Lehrkräfte) und andererseits durch ein zyklisches Vorgehen aus theorie- bzw. empiriegeleiteter Entwicklung, Praxisanwendung, Analyse und Re-Design (i.e. eine Anpassung der Lernumgebung und das erneute Durchlaufen eines solchen Design-Zyklus) (Feulner et al., 2021).



**Abbildung 3: Schemadarstellung des „Design-based Research“-Ansatzes**  
 Quelle: Feulner et al., 2021, S. 25.

Einen chronologischen Überblick über das dieser Dissertation zugrunde liegende DBR-Gesamtprojekt zeigt Abbildung 4. Die Einzelbeiträge der kumulativen Dissertation sind darin farblich markiert. Diese sind:

**Beitrag 1:** Brumann, Sebastian, Ohl, Ulrike, Schackert, Carolin (2019): Researching climate change in their own backyard – inquiry-based learning as a promising approach for senior class students. In Walter Leal Filho, Sarah L. Hemstock (Eds.): *Climate Change and the Role of Education* (pp. 71-86). Cham: Springer. [https://doi.org/10.1007/978-3-030-32898-6\\_5](https://doi.org/10.1007/978-3-030-32898-6_5)

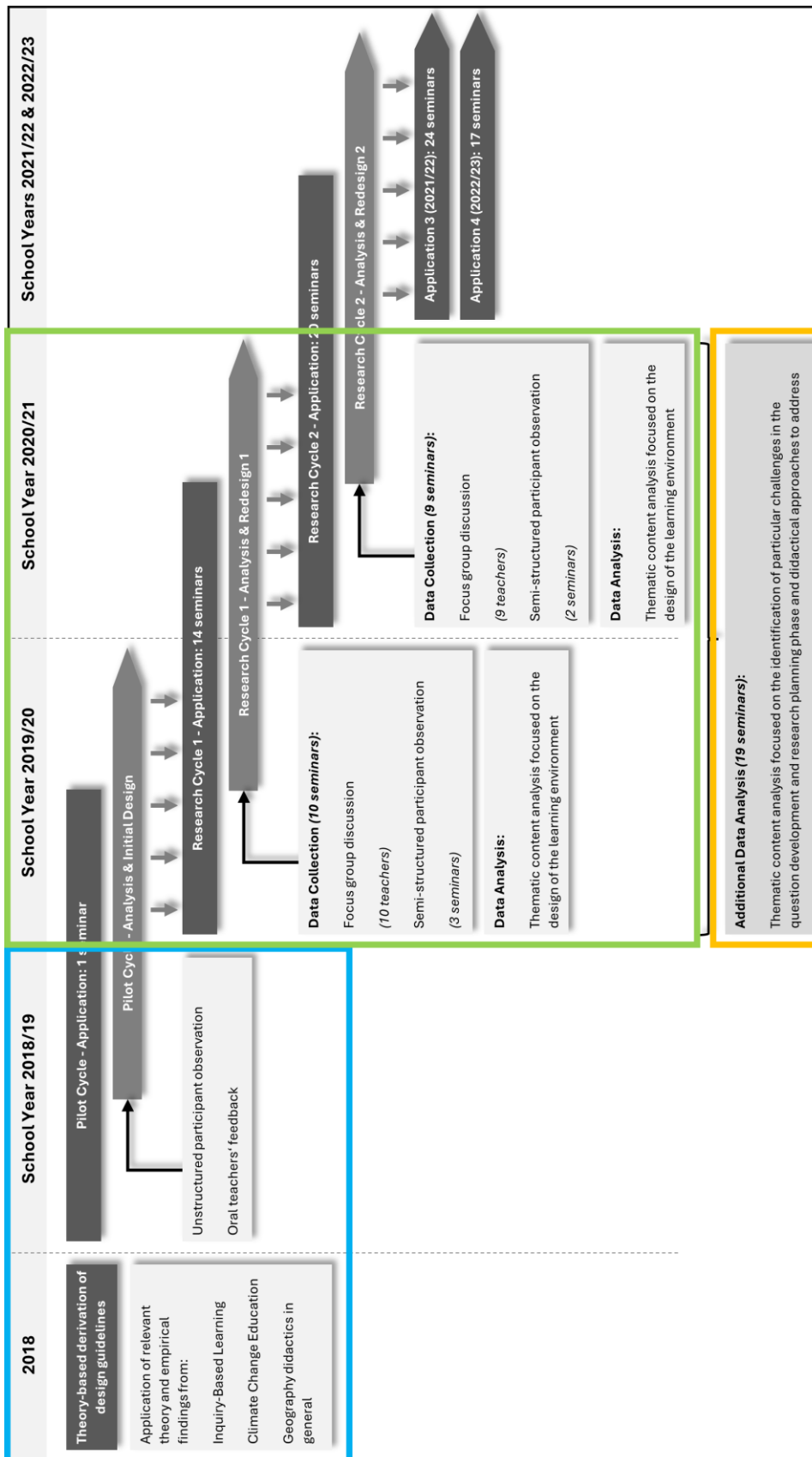
Dieser Beitrag klärt systematisch die didaktischen Potentiale des Forschenden Lernens für die Climate Change Education und analysiert zentrale Charakteristika einer ersten Pilotversion der Lernumgebung.

**Beitrag 2:** Brumann, Sebastian, Ohl, Ulrike, Schulz, Johannes (2022): Inquiry-based learning on climate change in upper secondary education: a design-based approach. *Sustainability*, 14(6), 3544. <https://doi.org/10.3390/su14063544>

Dieser Beitrag beschreibt ausführlich die forschungsbasierte Weiterentwicklung der Lernumgebung über zwei Hauptforschungszyklen hinweg und stellt das resultierende Produkt sowie die ihm zugrundeliegenden ausdifferenzierten Designprinzipien zusammenfassend dar.

**Beitrag 3:** Brumann, S., & Ohl, U. (2026). Finding a research question and developing a research plan in upper secondary school inquiry-based learning: Challenges and guidance approaches. *International Journal of Science Education*, 1–24. <https://doi.org/10.1080/09500693.2025.2612069>

Dieser Beitrag zeigt die besondere Bedeutung der Fragefindungs- und Forschungsplanungsphase beim forschenden Lernen auf, analysiert anhand von Daten aus den beiden Hauptforschungszyklen systematisch die besonderen Herausforderungen dieser Phase C und leitet darauf zugeschnittene didaktische Maßnahmen ab.



**Abbildung 4: Chronologischer Überblick über das DBR-Gesamtprojekt**  
Hervorgehoben sind die Einzelpublikationen der kumulativen Dissertation (**Blau** = Beitrag 1, **Grün** = Beitrag 2, **Orange** = Beitrag 3).

Quelle: verändert nach Brumann & Ohl, 2026.

### 3.2 Die besonderen Potentiale des Forschenden Lernens für die Climate Change Education - Beitrag 1

Bei der Beschäftigung mit der Fachliteratur zu Forschendem Lernen über unterschiedliche fachliche Disziplinen, Altersstufen und nationale Bildungskontexte hinweg zeigt sich eine Vielzahl an erfreulichen Ergebnissen und Wirkungen, die aus der Anwendung des Ansatzes hervorgehen können. Daraus zeichnet sich ein großes Potential ab, das auch für Bildungsprozesse zum Klimawandel nutzbar gemacht werden kann. Zum Zeitpunkt der Entstehung des interdisziplinären Forschungsverbunds *BAYSICS*, aus welchem sich das dieser Arbeit zugrunde liegende Forschungsprojekt entwickelt hat, stand eine systematische Klärung der spezifischen Potentiale Forschenden Lernens für die Climate Change Education allerdings noch aus.

Genau hier setzt Beitrag 1 („Researching Climate Change in Their Own Backyard – Inquiry-based Learning as a Promising Approach for Senior Class Students“) an. Da zur Eignung Forschenden Lernens für die CCE bis dato keine empirischen Erkenntnisse vorlagen, wurde im Rahmen des Beitrags systematisch Literatur analysiert, die – beziehend auf die unter 1.2.1 bereits umrissenen Herausforderungen der Climate Change Education – Erkenntnisse hinsichtlich dieser Potentiale ermöglichte. Dabei wurde auch auf Beiträge zurückgegriffen, die einem allgemeineren Diskurs zu Forschendem Lernen entstammen, oder der Climate Change Education sowie der Geographiedidaktik im Allgemeinen zuzuordnen sind. Es handelt sich dabei nicht um ein systematisches Literature Review, das streng den dafür üblichen methodischen Regeln folgt – dennoch wurde dabei gezielt und systematisch vorgegangen, mit dem Ziel, möglichst die gesamte diesbezüglich relevante Literatur mit einzubeziehen. Mit Blick auf das in Teilprojekt 8 von *BAYSICS* intendierte Ziel, eine Lernumgebung nach dem Ansatz des Forschenden Lernens im Rahmen eines „W-Seminars“ der bayerischen gymnasialen Oberstufe zu entwickeln, umreißt der Beitrag zudem in Grundzügen die zentralen Designentscheidungen bzw. didaktischen Elemente der Pilotversion der Lernumgebung, welche aus der Literaturrecherche gezielt für die Konzeption eines solchen „W-Seminars“ abgeleitet wurden.

Die Literaturanalyse macht deutlich, dass Forschendes Lernen u.a. drei zentrale Problemfelder der CCE adressiert: die faktische und ethische Komplexität des

Themas, die Persistenz von Präkonzepten sowie die psychologische Distanz vieler Lernender gegenüber den Folgen des Klimawandels.

Erstens eignet sich Forschendes Lernen, um die Komplexität des Klimawandels zu adressieren. Mit dem Durchlaufen authentischer wissenschaftlicher Prozesse können nicht nur fachliche (z.B. solides Wissen zu Treibhauseffekt, Klimafolgen, Rückkopplungen im Klimasystem etc.), sondern auch methodische (z.B. systematische Adressierung komplexer Probleme durch Datenerhebung, -analyse, und kritische -interpretation), soziale (z.B. Kooperation / Kollaboration, Aushandlung von Meinungen und Handlungsoptionen) und epistemische Kompetenzen (z.B. Umgang mit Unsicherheit, vorläufigem Wissen oder konkurrierenden Deutungen) gefördert werden, die für den Umgang mit mehrdimensionalen Problemfeldern wie dem Klimawandel unerlässlich sind. Studien belegen insbesondere den Zugewinn an kritischem Denken, Informationskompetenz und Problemlösefähigkeit, die auch im Kontext von Bildung für nachhaltige Entwicklung und den „21st Century Skills“ zentral sind (Apedoe et al., 2006; Kuisma, 2017).

Zweitens bietet Forschendes Lernen eine geeignete Möglichkeit, Fehlkonzepte zu bearbeiten und einen Conceptual Change zu initiieren. Da Lernende im Forschungsprozess eigene Vorannahmen und Hypothesen mit empirischen Daten konfrontieren, können wissenschaftlich undifferenzierte Vorstellungen – etwa über den Treibhauseffekt – durch überprüfbare Erfahrungen herausgefordert und modifiziert werden. Fehlannahmen können an der eigenen Erfahrung scheitern und dann analog zu wissenschaftlichen Hypothesen hinterfragt, angepasst oder verworfen werden (Chinn et al., 2013; Kukkonen et al., 2013).

Drittens kann Forschendes Lernen der psychologischen Distanz entgegenwirken, indem es Forschung an lokalen Beispielen ermöglicht und so globale Phänomene in lebensweltlich erfahrbare Kontexte einbettet. Untersuchungen zeigen, dass räumliche und zeitliche Nähe die Wahrnehmung von Relevanz erhöht und die Bereitschaft zur Auseinandersetzung fördert (Chiari et al., 2016). Zugleich ermöglicht Forschendes Lernen Selbstwirksamkeitserfahrungen: Wer eigene Daten erhebt und auswertet, kann unmittelbar erfahren, dass Forschung zu komplexen Fragen auch „vor der eigenen Haustür“ möglich und sinnvoll ist. Solche Erfahrungen können ein wichtiger Gegenpol zu Gefühlen von Ohnmacht und

Resignation sein, die im Zusammenhang mit dem Klimawandel häufig beschrieben werden (Gray, 2018; Sjödahl Hammarlund et al., 2013).

Diese Erkenntnisse greift die in BAYSICS-Teilprojekt 8 entwickelte Lernumgebung auf und bettet sie in den institutionellen Rahmen des „W-Seminars“ in der bayerischen gymnasialen Oberstufe ein. Dieses Format eines wissenschaftspropädeutischen Seminars bietet mit 1,5 Jahren Laufzeit besondere Voraussetzungen dafür, Schüler:innen systematisch an wissenschaftliches Arbeiten heranzuführen. Aus der Perspektive eines Schulfachs (hier Geographie) durchlaufen sie in dem im Rahmen dieser Arbeit entwickelten Konzept einen gesamten wissenschaftlichen Forschungszyklus:

*Erarbeitung fachlicher Grundlagen:* Zur Einführung in das Thema und zur Verknüpfung mit Alltagsbezügen dienen eigens entwickelte interaktive Online-Lernmodule, die Grundwissen zu den Ursachen, Funktionsweisen und Auswirkungen des Klimawandels, seinen regionalen Implikationen sowie forschungsmethodischen Zugängen zu diesem Themenkomplex vermitteln.

*Entwicklung individueller Forschungsfragen:* Auf der Basis persönlicher Interessen formulieren die Schüler:innen individuelle Fragestellungen und wählen geeignete methodische Zugänge, unterstützt durch Kreativtechniken, Strukturierungshilfen und praxisorientierte Anleitungen.

*Feldforschung:* „Vor der eigenen Haustür“ führen Schüler:innen eigenständig Datenerhebungen (z.B. Beobachtungen, Messungen, Interviews, Befragungen, Klimadatenanalysen) durch. Begleitend finden regelmäßige Treffen mit der Lehrkraft und den Mitschüler:innen zur Diskussion und Unterstützung statt.

*Zwischenpräsentationen:* Vor den Sommerferien stellen die Schüler:innen erste Ergebnisse vor. Diese Präsentationen dienen als Orientierung über den Lernfortschritt, Kommunikationsübung und Grundlage für die weitere Arbeit.

*Wissenschaftliches Schreiben und Abschluss:* In Workshops erarbeiten die Schüler:innen ihre Seminararbeit, unterstützt durch Reflexion, Peer-Feedback und gemeinsames Diskutieren. Abgeschlossen wird das Seminar mit einer öffentlichen Präsentation der Ergebnisse.

### 3.3 Systematische, forschungsbasierte Entwicklung und iterative Optimierung einer geographischen Lernumgebung zum Klimawandel für die gymnasiale Oberstufe nach dem Ansatz des Forschenden Lernens – Beitrag 2

Zwar gibt die oben beschriebene Literaturanalyse einen guten und fundierten Überblick über die Potentiale Forschenden Lernens und erlaubt zudem die Ableitung grundlegender Designprinzipien sowie didaktischer Maßnahmen zu deren konkreter Umsetzung. Zugleich zeigt die Analyse aber auch, dass vor allem wissenschaftsnahes Forschendes Lernen in der CCE bis auf wenige Ausnahmen an Schulen bisher kaum praktiziert wird. Dies gilt auch für das Fach Geographie, wo sich Forschendes Lernen häufig auf überschaubare Experimente beschränkt, während umfassende Forschungszyklen kaum realisiert werden. Die Gründe dafür sind vielschichtig, überwiegend aber durch curriculare Zeitrestriktionen, die hohe fachliche und methodische Komplexität sowie mangelnde Forschungserfahrung vieler Lehrkräfte zu erklären. Dementsprechend mangelt es auch an empirischen Erkenntnissen zur Gestaltung und Implementierung von wissenschaftsnahem Forschendem Lernen in der Schule im Allgemeinen sowie im Kontext der CCE im Speziellen. Daraus ergibt sich der Bedarf der systematischen, forschungsgeleiteten Entwicklung einer solchen Konzeption.

An dieser Stelle setzt Beitrag 2 („Inquiry-Based Learning on Climate Change in Upper Secondary Education: A Design-Based Approach“) an, der untersucht, wie ein wissenschaftspropädeutisches Seminar zu regionalen Klimawandelfolgen gestaltet sein muss, um erfolgreiches Lernen in einem wissenschaftsnahen Ansatz Forschenden Lernens zu ermöglichen. Die Forschung orientiert sich dabei an zwei Leitfragen:

- Welche theoretischen Designprinzipien lassen sich für wissenschaftsnahes forschendes Lernen in der Oberstufe identifizieren?
- Wie können diese Prinzipien für die Zielgruppe praktisch operationalisiert werden?

Die Studie folgt dem unter 3.1 bereits beschriebenen DBR-Ansatz, der Theorie- und Praxisentwicklung empiriebasiert verbindet. Dazu wurden zunächst aus der

Literatur sowie unter Einbezug des Erfahrungswissens der beteiligten Forscher:innen und Praktiker:innen übergeordnete Design-Guidelines abgeleitet. Diese wurden zu einem Set an detaillierten Umsetzungsprinzipien und konkreten didaktisch-methodischen Entscheidungen (z. B. Aufgaben, Materialien, Methoden) ausdifferenziert, welches die Grundlage für das in Beitrag 1 umrissene Pilotkonzept darstellte. In zwei aufeinanderfolgenden Hauptforschungszyklen mit insgesamt 34 Lehrkräften und 433 Schüler:innen wurden sowohl die Lernumgebung selbst als auch das ihr zugrunde liegende Set an Designprinzipien weiterentwickelt. Für eine möglichst differenzierte und tiefenscharfe Analyse wurde dabei auf eine qualitativ ausgerichtete Methodentriangulation aus Fokusgruppendifkussionen mit beteiligten Lehrkräften, teilstandardisierten Lehrkräftebefragungen sowie teilnehmenden Beobachtungen durch Forschende im Unterricht zurückgegriffen. Die Daten (digitalisierte Beobachtungsbögen, Protokolle und Transskripte von Fokusgruppendifkussionen, schriftliche Feedbacks der Lehrkräfte) wurden mittels qualitativer Inhaltsanalyse ausgewertet (Kuckartz, 2018). Dabei wurden die identifizierten Designprinzipien in ihrer Relevanz und Wirksamkeit hinsichtlich der Förderlichkeit für erfolgreiche Lernprozesse geprüft, induktiv ausdifferenziert und ergänzt und schließlich als Grundlage für die iterative Überarbeitung des Seminarkonzepts herangezogen.

Aus der forschungsbasierten Ausdifferenzierung der Designprinzipien über den Pilotzyklus und die beiden Hauptzyklen hinweg entstand eine Lernumgebung mit einer klaren Lernschritt-Struktur, systematisch begründeten didaktisch-methodischen Entscheidungen, Aufgaben, Methoden und Materialien. Wichtige Anpassungen der Lernumgebung bezogen sich beispielsweise auf die folgenden Punkte:

Durch die Ergänzung fester Reflexionssitzungen, interaktiver Lernschritte und Alltagsbezüge während der Erarbeitung von fachlichen Grundlagen konnten Motivation und Lernerfolg im Vergleich zu langen Online-Selbstlernphasen gesteigert werden. Zudem ermöglichen Spezialisierungsmodule früh die Orientierung an individuellen Interessen.

Die Feldforschungsphase brachte ein hohes Maß an Freiheit und eigenverantwortlichem Arbeiten, aber auch das Risiko von Überforderung. Anpassungen wie gestaffelte Einzelberatungen sowie Materialien zur schriftlichen

Dokumentation des Forschungsfortschritts erwiesen sich als hilfreich. Insgesamt zeigte sich, dass eine gute Balance von Peer-Feedback und Feedback durch die Lehrkraft zentral für den Lernerfolg ist.

Die finale Lernumgebung, die aus den beiden Hauptforschungszyklen hervorging, wurde in Form eines umfassenden Manuals für Lehrkräfte konsolidiert und publiziert (Brumann et al., 2022a), welches detaillierte Stundenverlaufspläne, Arbeitsmaterialien, Informationsressourcen, Tipps und Hinweise für den gesamten eineinhalbjährigen Seminarverlauf enthält und diese um theoretische Hintergründe zum Forschenden Lernen ergänzt. Das Manual ist dieser Dissertationsschrift in der aktuellsten Fassung vom 03.02.2022 angefügt (siehe Anhang 1).

Eine wichtige Erkenntnis aus den beiden Forschungszyklen war zudem, dass eine so ausgeprägte Form wissenschaftsnahen Forschenden Lernens mit außergewöhnlich hohen Anforderungen sowohl an fachliche, methodische und organisatorische als auch situative Diagnose- und Unterstützungskompetenzen von Lehrkräften einhergeht. Daher wurde auf der Grundlage der Forschungsdaten auch das Manual zum W-Seminar stetig um Hinweise, Tipps, Erwartungshorizonte, Ausarbeitungsbeispiele und weitere Unterstützungsangebote ergänzt.

Mit der Operationalisierung der identifizierten Designprinzipien auf drei Hierarchieebenen liefert die Studie darüber hinaus einen umfassenden und detaillierten theoretischen Forschungsoutput, der sowohl als Ausgangspunkt für darauf aufbauende Forschung als auch im Sinne von „How-to“-Guidelines für die Bildungspraxis Bezugspunkte schafft. Das finale Set an Designprinzipien ist dieser Dissertationsschrift als Anhang 2 angefügt.

### 3.4 Findung einer Forschungsfrage, Entwicklung eines methodischen Designs und Erstellung eines Forschungsplans als neuralgische Phase beim forschenden Lernen – Beitrag 3

Aus der Forschungsliteratur zu Forschendem Lernen, insbesondere in seinen wissenschaftsnahen Ausprägungsformen, zeichnet sich ab, dass gerade die Phase im Verlauf des Forschungszyklus, in der Schüler:innen zielführende individuelle Forschungsfragen entwickeln und das methodische Vorgehen für ihre Forschungsprojekte planen sollen, eine außerordentliche Herausforderung darstellt

(Beyerlin et al., 2020; Bell et al., 2010; Guo et al., 2018; van der Schee, 2001). Zugleich sind die Lernschritte und -produkte in dieser Phase wegweisend für den Erfolg aller weiterer Phasen der Forschungsprojekte der Schüler:innen. Die im Rahmen von Beitrag 2 über die beiden Hauptforschungszyklen hinweg erhobenen Daten unterstreichen dies sehr umfassend und deutlich. Zwar sind einschlägige Schwierigkeiten, die während dieser Phase auftreten können, in der Literatur teils auch empirisch dokumentiert (vgl. z.B. Beyerlin et al., 2020) – dennoch fehlen bislang einerseits eine detaillierte und systematische Beschreibung dieser Schwierigkeiten und andererseits umfassendere konkrete Erkenntnisse dazu, wie man diese Phase didaktisch gezielt unterstützen kann.

Hier setzt Beitrag 3 an, der in Bezug auf die in Beitrag 2 entwickelte Lernumgebung den folgenden Fragen nachgeht:

- Welche besonderen Herausforderungen lassen sich bei der interessen geleiteten Entwicklung individueller Forschungsfragen durch die Schüler:innen sowie bei der methodischen und organisatorischen Planung ihrer Forschungsaktivitäten feststellen?
- Welche didaktischen Ansätze eignen sich, um die identifizierten Herausforderungen zu adressieren?

Um diese Fragen zu beantworten, greift die Studie auf die Daten zurück, die bereits im Rahmen von Beitrag 2 über die beiden Hauptforschungszyklen hinweg erhoben wurden. Anhand dieser Daten wurden erweiterte thematische qualitative Inhaltsanalysen durchgeführt, um Hinweise auf Lernschwierigkeiten differenziert zu erfassen und zu übergeordneten Herausforderungskategorien zu bündeln. Dabei wurden auch potentielle Einflussfaktoren sowie die Kontextabhängigkeit von Lernschwierigkeiten erfasst. Schließlich wurden die über die beiden Forschungszyklen hinweg vorgenommenen Unterstützungsmaßnahmen und Überarbeitungen hinsichtlich ihrer Wirksamkeit überprüft, indem analysiert wurde, inwiefern die eingeführten Anpassungen zu erkennbar verbesserten Lernprozessen führten.

Die Datenanalyse brachte neun zentrale Problemkerne hervor, die über die beiden Hauptforschungszyklen hinweg während der Phase der Frageentwicklung und Forschungsplanung beobachtet werden konnten. Diese hängen oftmals miteinander zusammen und können sich wechselseitig beeinflussen:

- Fehlendes Wissen über Forschung bzw. mangelnde Vorerfahrung mit Forschungsprozessen / forschendem Lernen.
- Unzureichendes Verständnis der Abfolge, Funktionen und/oder Ziele von Lernschritten.
- Fehlende bzw. unzureichende Heuristiken für bestimmte Lernschritte.
- Schwierigkeiten, bei der Planung von Forschungsprozessen mit inhärenten Ungewissheiten umzugehen.
- Probleme mit kooperativen Aktivitäten, die auf mangelnde Bereitschaft oder Fähigkeit zu Peer-Feedback, Reviews o.ä. zurückgehen.
- Schwierigkeiten, sich (statt der Bearbeitung vorgegebener Themen) eigener Interessen bewusst zu werden und diese zu verfolgen.
- Schwierigkeiten bei der selbstgesteuerten Durchführung von Lernprozessen.
- Empfundene Überforderung durch besonders umfangreiche oder schwierige Lernschritte.
- Motivationale Schwierigkeiten im Verlauf der Lern- / Forschungsprozesse.

Diese Schwierigkeiten resultieren maßgeblich aus der Unvertrautheit mit der Logik, den Methoden und der Epistemologie von Forschendem Lernen, welche wiederum stark auf Lerngewohnheiten, Schulkultur und curriculare sowie strukturelle Rahmenbedingungen zurückzuführen ist. Dass über das Design von Lernumgebungen trotzdem didaktische Lösungen bereitgestellt werden können, die Schüler:innen auch unter den bestehenden Rahmenbedingungen dazu befähigen, Forschungsfragen, methodische Designs und Forschungspläne zu entwickeln, konnte in der Studie ebenfalls gezeigt werden. Diese didaktischen Maßnahmen lassen sich thematisch zu elf übergeordneten Ansätzen zusammenfassen, die in der Lernumgebung je nach Lernschritt, Situation und Kontext unterschiedlich realisiert wurden:

- Umfassende Vorbesprechung der Fragefindungs- und Forschungsplanungsphase.
- Advance Organizer, um Lernschritte transparent zu machen.
- Vorbesprechung von Lernschritten und/oder der dazugehörigen Materialien.

- Explizierung / Bewusstmachen der Interessen der Schüler:innen.
- Formulierung von Lernaufgaben: Präzise, verständlich, anschaulich, an das erwartbare Vorwissen der Schüler:innen angepasst, die individuellen Ideen der Schüler:innen aufgreifend.
- Bereitstellung klarer Richtlinien, Kriterien, Hilfestellungen und/oder Heuristiken für einzelne Forschungsschritte.
- Anschauliche Beispiele für die intendierten Ergebnisse der Lernschritte.
- Individuelle Selbstlernphasen, in denen sich die Schüler:innen vertieft mit ihren Themen auseinandersetzen können.
- Gelegenheiten zum Üben kooperativer Aktivitäten
- Anweisungen, Hinweise, Vorschläge und Informationsmaterialien für Lehrkräfte
- Angemessene Strukturierung der Lernschritte (Reihenfolge, Dauer und Verteilung über die Sitzungen)

## **4 Einzelbeiträge der kumulativen Dissertation**

Die in Kapitel 3 umrissenen Forschungsbeiträge sind im Folgenden als Volltext abgedruckt.

### **4.1 Beitrag 1: Researching Climate Change in Their Own Backyard – Inquiry-based Learning as a Promising Approach for Senior Class Students**

Der nachfolgende Beitrag ist 2019 im Sammelband „Climate Change and the Role of Education“ erschienen. Für die bibliographischen Angaben siehe Brumann et al. (2019) im Literaturverzeichnis.

Bei der hier abgedruckten Version handelt es sich um das final beim Verlag zur Veröffentlichung eingereichte Manuskript. Dieses wurde inhaltlich unverändert veröffentlicht, jedoch in Format bzw. Layout vor dem Druck durch den Verlag noch angepasst.

# **Researching Climate Change in Their Own Backyard – Inquiry-based Learning as a Promising Approach for Senior Class Students**

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## **Abstract**

Inquiry-based learning (IBL) enables students to personally experience climate change, which is often perceived as a rather abstract phenomenon. This article outlines characteristics of the IBL approach and sums up its most important benefits for climate change education. Recent relevant school projects, which address the topic of climate change, are presented. The article then describes main features of a prototypical IBL concept, which is being developed at the Chair of Geography Education at the University of Augsburg. In this project, Bavarian senior class high school students conduct research on the effects of climate change in their immediate surroundings. They work on individually generated study questions using anthropogeographic and physiogeographic research methods. In order to do so, students are led towards a deeper understanding of the regional implications of climate change by working with online learning modules that additionally present adequate research methods. They also present their scientific findings in front of peers, a broader public and climatologists. Finally, first findings of the project portrayed above are discussed.

## **Key words**

climate change education, inquiry-based learning, fieldwork, regional implications of climate change, complexity

## **1 Teaching Climate Change – A Relevant and Challenging Matter**

Current and pressing challenges of global climate change not only require corrective measures by governments and economy but also climate literate behaviour of the individual. Students, in particular, can make climate conscious decisions in areas such as personal mobility, holiday destinations, recreational activities, nutrition, consumerism, energy consumption and, partly, housing (Chiari et al. 2016).

Studies have shown that a certain climate literacy, i.e. basic knowledge about climate change as an issue as well as its causes and possible effects, does exist, at least in Central European societies (Chiari et al. 2016). At the same time, there is a frequently described discrepancy between a person's awareness or knowledge of climate change on the one hand and their actions on the other hand: although the risks of climate change are considered relevant, most people do little to counteract it (Renn 2018). A Europe-wide survey showed that especially

people below the age of 24 contribute considerably less to climate-conscious behaviour than older groups (European Commission 2014). Personal factors that influence climate literate behaviour and help to explain this discrepancy are diverse. Chiari et al. (2016) illustrate that these factors can be both personal (as for example knowledge, values and attitudes, interests, perceived self-efficacy) and situational (as for example available infrastructure, economic circumstances or social context).

School education, especially geography education, is responsible for contributing to adequate climate change education by positively influencing the above-mentioned factors, as best as educational settings allow. In this context, teaching knowledge of climate change as well as the ability to act sustainably are crucial goals. As already mentioned, it is clear that the dissemination of knowledge alone does not automatically lead to climate literate behaviour. However, knowledge is an essential prerequisite for it. Results from a study by Ranney and Clark (2016) among American citizens are encouraging, as they show that the acceptance for anthropological climate change as well as the willingness to act grew with an understanding of the greenhouse effect. Additionally, these findings could be replicated in another study with German participants (Ranney and Clark 2016).

The didactic challenges that arise in connection with climate change education result in particular from the topic's complexity as well as a perceived temporal and spatial detachment from impacts of climate change.

### *The Complexity of Climate Change*

Climate change is a complex issue on both a factual and an ethical level, as it is characterised by a tension between numerous interconnected aspects such as economic interests, ecological goals, cultural orientations, social norms and political decisions (Meyer et al. 2018).

Approaches from both sciences and humanities are necessary to cover the subject adequately, assess its risks and find viable solutions (Meyer et al. 2018). As another facet of its factual complexity, it is local and global factors that play a role as well. With this in mind, factual complexity is then complemented by an ethical dimension. This becomes visible in the ongoing discussion on climate justice, for example.

In light of these complexities, it is not a surprise that international research in the field of Conceptual Change has uncovered challenges in teaching about climate change. Much of the research conducted shows that students often have wrong, highly persistent conceptions of climate change, especially with regard to the causes of climate change and possible solutions and, to a lesser degree, with respect to the impact of climate change (see Felzmann 2018 for a summary). Many children and adolescents mistakenly assume that the ozone hole is the cause of the anthropological greenhouse effect. Furthermore, without further differentiation, students often attribute the greenhouse effect to "emissions" that supposedly destroy the ozone layer. Another common misconception is that of a confined CO<sub>2</sub> or greenhouse gas layer in high altitudes (Schuler 2011, Felzmann 2018). Reinfried and Tempelmann (2014) show that scientific misconceptions formed prior to classes on the topic of climate change play a significant role in it. Depending on the characteristics of these scientific misconceptions, they may or may not be modified by learning environments, which are specifically designed to target them. Overall, research has shown that actively formulating and working with misconceptions is more effective than ignoring them (Felzmann 2018). Attempts to explain the above-mentioned difficulties go beyond the topic's complexity as they also include the fact that, especially to people living in Central Europe, the mechanics of climate change are only perceivable to a small degree. Correspondingly, most people do not have personal experiences with climate change (Renn 2018). According to Reinfried (2007), in this case, many people might fall back on unscientific categories, which might lead to a causal connection of aspects such as the metaphoric term ozone hole, personally perceived

temperature fluctuations, conceptions of a greenhouse glass ceiling and self-experienced higher concentrations of near-ground ozone.

### *Perceived Spatial and Temporal Detachment*

In Central Europe and other regions of the world, the effects of climate change can only be perceived to a small degree, which causes a so-called “psychological distancing”, i.e. a perceived spatial and temporal detachment from impacts of climate change. Consequently, people tend to ascribe them to other parts of the world (e.g. islands in the South Pacific Ocean) and a distant future (Chiari et al. 2016). In a study conducted with students of German high schools, Fiene (2014) shows that adolescents predominantly believe that climate change only happens on a global scale and that they consider climate change irrelevant to their own home. Consequently, they pay scant attention to the gradual nature of climate change, whose effects are barely perceivable (Renn 2018). Furthermore, they do not feel affected, have a low sense of responsibility and little willingness to act against the impacts of climate change. Due to psychological distancing and the misguided belief that climate change is merely a global phenomenon, many people share the conviction that their opportunities for actions are very limited and that they, as individuals, cannot make a difference (Renn 2018).

### *Inquiry-based Learning as a Promising Approach*

Researching climate change in their own backyard through inquiry-based learning (IBL) can be an opportunity for students that may help to overcome psychological distancing as it is based on individual interests, takes place close to home and in social interaction with peers. In the following chapters, we will discuss potentials of inquiry-based learning for the topic of climate change in more detail. In addition, we will introduce our research project, in which students apply this very approach and summarise our experiences in a résumé.

## **2 IBL as a Promising Approach for Climate Change Education**

It is obvious that there is no universal solution for the challenges of climate change education, but certain approaches seem to be particularly suitable for such settings. One exemplary approach is inquiry-based learning, which facilitates and optimises climate change education, especially with regard to the difficulties outlined above.

### **2.1 What is IBL?**

Inquiry-based learning is not a uniformly defined concept, but rather an array of didactic approaches that cover a wide range of educational areas and disciplines and can take different forms as well as names (Reitinger 2013, Brumann and Ohl 2019). However, all of them share a core of principal characteristics that, in light of the school context, can be described as a form of learning that aims for searching and finding insights, which are new at least to the learner, but can also be of interest to third parties. Attitudes and methods of inquiry-based learning are analogous to the fundamental mindset and approaches of scientific work (Messner 2009, Huber 2009). This means that, during their learning process, students partly or fully complete a typical scientific research cycle by developing questions and hypotheses, choosing and applying appropriate methods and then analysing, interpreting and presenting results (Huber 2009, Reitinger 2013, Pedaste et al. 2015). The goal is to apply and consequently acquire scientific core competences. These include both receptive research skills, such as information literacy, statistical literacy and critical thinking, as well as productive research skills. The latter include cognitive competences such as knowledge about research processes and methods, the generation of hypotheses or data analysis, affective-motivational competences such as research-related self-efficacy or a tolerance of uncertainty

and ambiguity, and the social competence of cooperation in a learning community (Gess et al. 2017). Furthermore, IBL should at best require and encourage a so-called research attitude. According to Gess et al. (2017), this includes a reflexive distance – i.e. a reflective, questioning attitude – epistemic curiosity, in the sense of an intrinsically motivated tendency to find out new things (Kidd and Hayden 2015), as well as differentiated epistemological beliefs, i.e. the assumptions of a person about the nature of knowledge and the process of knowledge acquisition (Klopp and Stark 2016).

The range of didactic approaches, which correspond, at least in essence, to this basic character of IBL, is broad and varies in a number of dimensions. On the one hand, there are forms of teaching, which (for didactic and/or organisational reasons) are greatly simplified; they are pre-structured, narrowly focused and, hence, rather less scientific. On the other hand, there are approaches that can be very close to the model of scientific research, especially with an increasing age of the learners and in higher and adult education. As a rule, such concepts are only feasible as long-term projects. Their characteristics are that students work successively, on the basis of their own curiosity and questions and with a high level of self-control on complex topics that are closely connected to their everyday lives. With respect to content and methodology, the concepts align with (at times integrative) approaches from the humanities and natural science and/or humanities. Findings are then often of importance to third parties, i.e. their relevance goes beyond the individual learning processes (Brumann and Ohl 2019).

## **2.2 Potentials: How Can IBL Face the Above Mentioned Challenges?**

There are many good reasons that argue for inquiry-based learning from an educational and scientific theoretical point of view. Also with regard to the challenges that successful education of topics relevant to sustainability, such as climate change, brings along, inquiry-based learning has considerable potential. For example, since the students are constantly asked to autonomously find, define and structure problems as well as plan, conduct and analyse investigations in communication and cooperation with other learners, IBL requires and fosters specific competences, which are highly important with regard to student's everyday lives. Moreover, the management of resources, the making of decisions and the fact that students have to be able to endure ambiguity enhances this effect further. Kuisma (2017) showed that a corresponding set of so-called "twenty-first century skills" can be promoted through inquiry-based learning. Many of these "design competences" can also be considered as important elements of education for sustainable development (ESD) (BLK Program Transfer-21 2007).

Among other things, Tilbury (2011) highlights the critical questioning of information as central to ESD. Especially in times of the internet and the concomitant complexity and controversy of available information, this is generally considered an important key skill. Relevant scientific studies have shown that inquiry-based learning has a positive effect on the ability to think critically (for example Apedoe et al. 2006 in the field of geology, or Uzunöz et al. 2018 in the sports sciences). Al-Maktoumi et al. (2016) observed that students participating in a hydrogeological research project in Oman adopted an increasingly critical questioning attitude. In some cases, on the basis of own experiences, this attitude even led to the questioning of common textbook knowledge. Especially in regard to science education, Duran and Dökme (2016) were able to show that IBL fosters a better development of critical thinking compared to conventional approaches.

In addition, IBL also offers a great potential for dealing with the above-mentioned students' scientific (mis-)conceptions. In order to make use of these conceptions and to enable a Conceptual Change in the sense of constructivist learning processes (see e.g. Reinfried 2007), Schuler (2011) postulates the need for interdisciplinary and systematic learning as well as the requirement to teach students the ability to acquire knowledge by themselves and to critically question this information. In addition, education about global climate change should aim at

the development of differentiated knowledge about problematic consequences, perpetrator roles and opportunities for action (Schuler 2011). Since these knowledge structures are often missing, it seems to be very important to make concrete, exemplary experiences. By the application of IBL, these experiences can possibly be produced to some degree. Because of a certain analogy between student's mental misconceptions and scientific hypotheses, which both have to be adapted or replaced when they fail through experience, this seems to be a promising approach. With the help of inquiry-based learning, students can succeed in empirically modifying the existing ideas by verifying concrete facts and scientific observations. According to this potential, Kukkonen et al. (2013) show that IBL has a positive effect on the students' perception of the greenhouse effect and the understanding of this phenomenon. More general, Chinn et al. (2013) show the potential of IBL for the promotion of Conceptual Change on the basis of selected studies and own investigations. The authors suspect that this is mainly due to the active negotiation of "evidence-theory linkages" in doing research.

Another advantage of researching a concrete – at best local – phenomenon is a potentially strong relevance to one's everyday life, which has been shown to be particularly favorable for the communication of climate issues among adolescents (Chiari et al. 2016). In doing so, IBL establishes a temporal and spatial proximity between the learner and the topic, because usually research projects are carried out in immediate vicinity to the student's own backyard. Accordingly, a special challenge of IBL is to put concrete experiences in a meaningful context with the rather abstract concept of climate change. However, if this is achieved through targeted didactic action, there is a tremendous opportunity to correspond to the general principle of meaningful global thinking. Pretorius et al. (2016) refer, for example, to the potential of IBL to apply relevant knowledge and competences on site and to reflect local challenges and opportunities. In other studies (e.g. Klein 1995), this could be identified as a necessity especially for geographic inquiry even more explicitly. Thus, access to a topic will be extended to an active and practical learning dimension, which is an important attribute of ESD (Tilbury 2011, Pretorius et al., 2016). However, this does not necessarily result in the reduction of psychological distancing, which in turn could favor an increased willingness to act, because environmental psychology has shown that people do not automatically care about proximal places and the elements, properties and qualities that constitute them (Brügger et al. 2015). Nevertheless, it is still very likely to create proximity to the object of learning through inquiry-based learning, because individual curiosity, interests and questions can be seen as the starting point of the learning processes. As a consequence, students devote themselves to these very aspects of their own immediate surroundings, which feature an exceptionally high potential of intrinsic motivation.

According to many research findings, own observation and research foster a better understanding of scientific concepts in particular (Markaki 2014). Especially in the field of Earth Sciences, two studies by Mao et al. (1998) and Chang and Mao (1999) should be mentioned, which showed that IBL promotes a generally greater learning success in researching geosciences compared to traditional approaches. In addition, the study by Klein (1995) also showed a notable increase in learning with regard to different geographic concepts and competences – including one topic on global climate change. Moreover, Namdar (2018) designed inquiry-based activities specifically on the topic of global climate change to provide future teachers with a tool to teach these relationships. The accompanying study showed a significant improvement in their understanding of global climate change.

An elaborate expertise, however, only represents one part of the felicity conditions for climate change education. The reduction of distance and abstractness can certainly facilitate the generally difficult step from knowledge to action. However, as explained above, a number of other important factors have to be added. In the research literature evidence can be found that these factors can possibly be supported by means of inquiry-based learning. It is a great

challenge for teaching to overcome fear and feelings of powerlessness in relation to climate change and to replace it with the sense of self-efficacy. Gray (2018) for example shows that research in the field of earth sciences has a positive effect on the feeling of self-efficacy expectations of future teachers. Also, Sjö Dahl Hammarlund et al. (2013) concluded on the basis of their research that IBL promotes participants' motivation and self-efficacy expectations. This connection may be explained by the fact that a research cycle requires the learners to deal with unexpected events, solve problems independently and overcome setbacks. Learners can gain a strong sense of efficacy in situations of that sort, if the design of the IBL allows positive experiences. Additionally, these experiences may be a potential antidote to the mass media news broadcast that overwhelmingly has a threatening character. Furthermore, tying in with the specific interests of each target group and the often heterogeneous interests within it, contributes to the success of climate communication. Various studies have shown that IBL leads to increased motivation among learners (e.g. Tuan et al 2005, Bayram et al. 2013). The authors explain this with the comparatively great freedom of choice learners have in IBL, in the sense that learners have the possibility to control their own learning processes and choose the topics and methods based on their interests.

Finally, the willingness to adopt climate-friendly behaviour depends on certain values: while helpfulness or benevolence seem to have a positive effect, values that focus on individual benefits tend to have negative effects on climate-friendly behaviour (Chiari et al., 2016). As values and attitudes are generally considered to be rather difficult to change, it is also difficult to make statements regarding the effect of inquiry-based learning. However, it can at least be assumed that one essential characteristic of scientific activity and, consequently, also IBL can make a contribution: research requires cooperation and communication as well as negotiating and bridging different perspectives, while "single-fighter mentalities" often make success more difficult.

Obviously, like any other form of learning, IBL does not per se achieve the aforementioned effects. The success of the method depends on the design of the respective concept. This includes a large number of didactic decisions, which can vary depending on the context. All in all, forms of inquiry-based learning that are very similar to science, which themselves imply a series of corresponding conceptual considerations and conditions of success, are more likely to produce the intended effects.

### **2.3 Recent Didactic Approaches that More or Less Meet the IBL Concepts**

In light of what has been described above, it is not surprising that current educational projects on climate change include, more or less extensively, elements of inquiry-based learning. A selection of the many examples of concepts that have been published in German recently are presented here:

#### *ReKli:B*

The interdisciplinary project *ReKli:B*, which took place between 2012 and 2016 at the Heidelberg University of Education, aims at promoting children's and adolescents' ability to evaluate regional climate change and their willingness to act upon it. Methodically, the concept is conducted with partner schools in the form of field studies, in-depth analyses in a geo-ecological laboratory and model- and experiment based approaches. Using local examples, it aims at making the ecological interrelations of climate change as comprehensible as possible. Based on several learning modules, participating students can conduct these research activities for different topics over a course of several lessons (Siegmond et al. 2017).

#### *Climate ChangeS Cities*

With *Climate ChangeS Cities* by the Ruhr-University in Bochum, the Trier University and the Heidelberg University of Education a new German educational project on climate change is under way. Inspired by *ReKli:B*, the project's emphasis is, again, on the enhancement of crucial competences such as evaluation and judgment skills and the capacity to act, and, in terms of content, the assessment of climate-related phenomena in urban spaces. *Climate ChangeS Cities* is based on the IBL approach described above, as students are enabled to self-directedly conduct investigations in their living environments, such as field observations in the city and laboratory work. Additionally, here based on the "experimental algorithm", students run through different stages of inquiry. According to first observation results, *Climate ChangeS Cities* seems to be a promising approach (Feja et al. 2019).

#### *k.i.d.Z.21*

The University of Innsbruck developed *k.i.d.Z.21* as a bi-national project in cooperation with a German school. It allows students to engage in individual subprojects, which can include questions on climate change from both the humanities and the sciences. Particularly noteworthy is the included five-day research stay in the Ötztal Alps, which ends the project of several months. As the effects of climate change are especially visible in mountain regions, the trip gives students the opportunity to experience the effects of climate change first hand and to investigate them independently by using geographical methods (Oberrauch et al. 2015).

### **3 The Augsburg Concept as an Exemplary IBL Approach in Climate Change Education**

The examples presented above give an insight into possible designs of inquiry-based learning in connection with the topic of climate change. Almost always, the details of the concept depend on the organisational and thematic requirements of the respective educational context. Very often, time is a limiting factor, especially in more scientific forms of IBL. Consequently, finding ways to implement IBL as prototypically as possible into the given educational contexts, is particularly challenging. At Bavarian secondary schools, the so called "W-Seminare" in years 11 and 12 are a framework that offers the chance to teach propaedeutics and therefore prepare students for scientific work at universities. Over the course of one and a half years, students are enabled to develop science-related competences and a general ability to study. From the perspective of one school subject, the W-Seminars are also meant to make inquiry-based learning possible (ISB 2011). Although there are already numerous best practice examples of W-Seminar concepts, the full potential, especially with regard to the intention to give students' learning processes a clear scientific character, has not yet been exhaustively realised. Aiming at meeting both the requirements of propaedeutics and climate change education, the Chair of Geography Education at the University of Augsburg is currently developing a subproject of the Bavarian *BaySICS* climate research project initiated in 2018. The basic idea of the concept is to involve students, based on the concept of Citizen Science, in researching regional and local implications of global climate change in Bavaria. They use the one-and-a-half-year period to complete a full scientific research process, which includes acquiring basic competences, finding and developing individual research questions, planning and conducting data collections, analysing, interpreting and communicating results and, eventually, writing a scientific paper (see Figure 1). In the following the didactic conception of the individual phases is briefly described:

#### *Development of the Factual Basis for the Topic of Climate Change*

The introductory lessons serve to give the students an organisational overview, make a first connection between the topic and their everyday lives and arouse curiosity. Following that, students shall delve into the topic for several weeks, paying special attention to regional

aspects. A modular structure, which has already proven beneficial in other projects, is used to introduce the factual basics prior to the research processes. There are several good reasons to make use of an online-based implementation: one main argument is the close relation to students' everyday lives, as most of them are confronted with online media contents on a daily basis. Therefore, it can be assumed that students not only show an affinity to such contents, but also basic technical competences in intuitively handling them.

At the same time, in contrast to analogue forms, online modules offer the chance to combine a wide range of learning materials (e.g. YouTube videos, audios, documents, hyperlinks to external databases, mapping services etc.) and thus different approaches. The *Onlinekurslabor* of the University of Augsburg, within which the modules have been realised, also offers the possibility of integrating a number of interactive tasks (e.g. multiple choice questions, drag and drop tasks, cloze tests) that already allow a certain amount of self-control in this first phase. As the concept is intended to be used at many different Bavarian schools, the online platform allows easy multiplication and the creation of a network for the participating schools. Additionally, a didactic system that includes current scientific findings – which are indispensable to a topic such as climate change – should be constantly modifiable. An online platform makes it possible to revise the content at a central point for all users.

At this point, the online course laboratory includes modules on "General basics of climate change", "Climate change perception", "Environmental protection", "Climate change and forest ecosystems", "Climate change related pollen pollution", "Phenology as an indicator of climate change" and "Climate change and tree line changes". Other modules on important anthropogeographic and physiogeographic topics are currently being developed.

#### *Development of Individual Research Questions and Planning of Data Collection*

The development of individual research questions based on personal interests plays an important role in inquiry-based learning (see chapter 2.1). Accordingly, in a second phase of the W-Seminar, students elaborate regionally embedded research questions as well as suitable methodical designs based on their own ideas and interests that they developed earlier on closer examination of the topic. On the one hand, creative techniques can be used to help students further develop and/or narrow down their topic. On the other hand, measures of structuring, orientation and support ensure the emergence of a scientific research question. In addition, short application-oriented "how-to" chapters on climate-related research methods in the online course laboratory help students to create an optimal matching between their question and survey design.

#### *Fieldwork*

Based on the now established individual research questions, they start the actual fieldwork in their own living environments comprising the processes of searching and discovering, observing and measuring, inquiring and documenting, as well as reflecting and analysing. Regular reflective and metacognitive approaches should empower students to expand their thinking through their own inquiry as well as to address the nature of science and their own epistemic beliefs. However, in such a significantly self-controlled phase, constant individual support as well as the exchange and cooperation in the peer group play a pivotal role. This is realised in the form of regular meetings, in which central findings can be discussed. In order to satisfy these aspects in the best possible way, it is particularly important to allow sufficient time. Due to the generous time frame of the W-Seminar concept, it is possible to allocate around three months for the fieldwork.

#### *Interim Presentations*

An intermediary milestone are the presentations of the preliminary research results that take place before the summer holidays. They fulfil several functions: On the one hand, they mark a first success for the students, because by that time some data has been collected, first findings are noted and preliminary interpretations are made, which means that every student has already produced knowledge in a "raw form". On the other hand, the preparation and structuring of this knowledge also creates the potential for further mental differentiations. Furthermore, drawing up a presentation is, at the same time, a precursory product, which sets the ground for the subsequent learning phases. This not only serves as an orientation for the individual student, but also gives the teacher supervising information about the progress of the respective research projects. Lastly, it should also be mentioned that these presentations strengthen the students' communication skills.

### *Scientific Writing and Thinking Workshops and Conclusion of the Seminar*

The last third of the W-Seminar focuses on the written elaboration of the individual research results in form of a term paper. Similar to the second phase of the seminar, the students should be provided with different measures of support to work out a written scientific paper comprising the necessary quality criteria. The central idea is to bring the social dimension of the acquisition of scientific knowledge into the classroom: Corresponding to symposiums, peer review procedures, interdisciplinary research projects, postgraduate programmes and the like, which characterise the scientific business as such, the students should perceive their own work as part of a knowledge-building community (see Scardamalia and Bereiter 2006). Accordingly, in this phase the individual inquiry is supplemented by regular seminar sessions with a workshop character, which primarily serve joint reflections and discussions, constructive criticism and mutual support. Besides the completion of the written term paper, the conclusive stage of the research process will be a final presentation, which gives the students the opportunity to present their results to an extended school public and to exchange ideas with interested specialists.

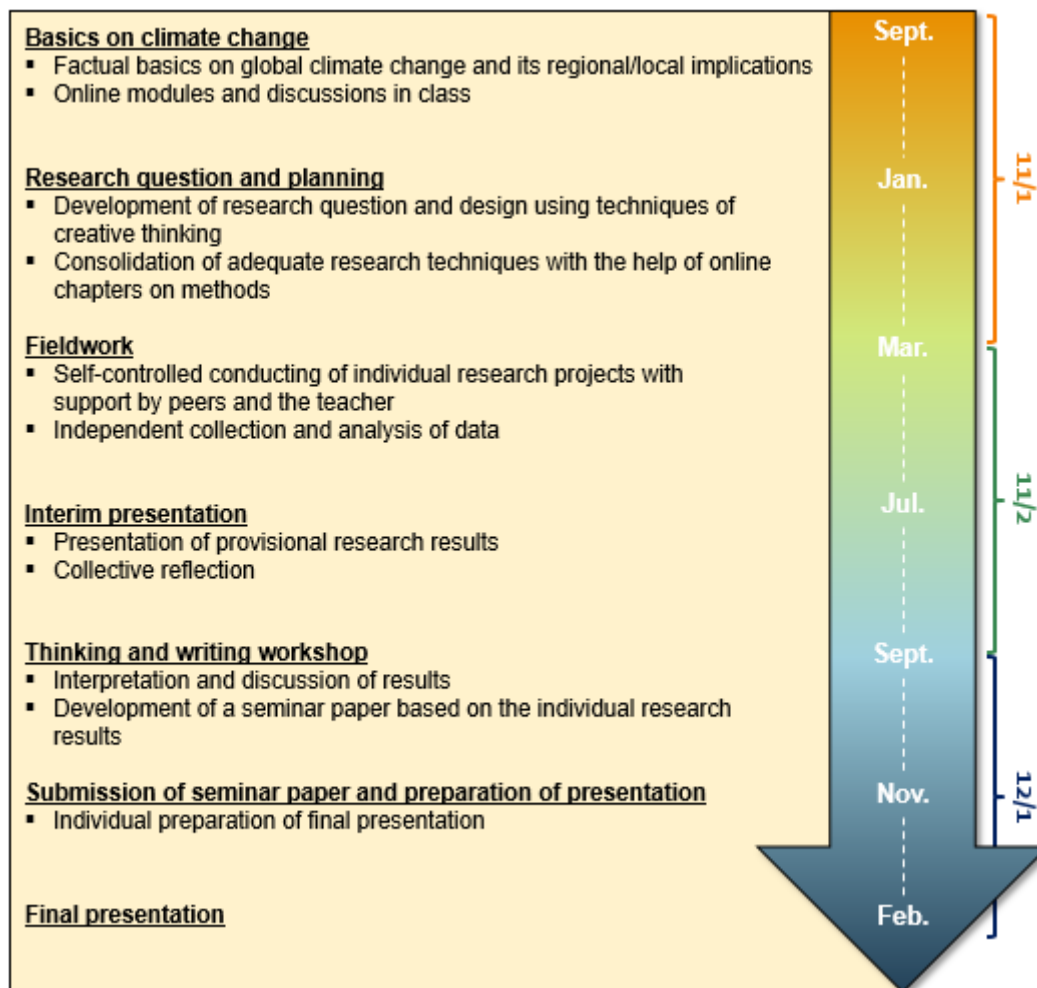


Figure 1: Overview of sequences of the W-Seminar on regional/local implications of climate change in Bavaria

#### 4 First Insights

The pilot stage of the seminar concept started in September 2018 with 14 students at a school in Augsburg. First experiences show that the following factors of the learning environment are relevant to successful learning:

##### *Social Interaction*

In the context of the previous activities, the role of sufficiently high proportions of social interaction became particularly obvious. This was especially evident in the first phase while working with the online learning modules. Whenever students discussed contents of the learning modules in class, a respectable learning progression and high level of motivation were apparent. Thus, several factors are potentially important: Firstly, the verbalisation of thoughts in the classroom requires a mental pre-structuring. Secondly, it could also be observed that the interrelated utterances of students and the teacher had a catalysing effect on the development of a common understanding. Thirdly, a classroom discussion establishes a particularly strong reference to everyday life. Although the learning modules were already designed with regard to the proximity of the contents to students' everyday life – e.g. by working with regional examples or tasks that aimed at the student's own experiences – in the vocal debriefings, students often resorted to self-selected current examples of specific local events or viral media issues. Moreover, in the context of oral interaction, it is also possible to

respond specifically to aspects that arise situationally. The desire for opportunities for exchange and a compulsory backup of (intermediate) results explicitly mentioned by the students stresses the considerable potential of classroom discussions further. In contrast, stages in which students had to work autonomously with the online modules for longer periods turned out to be unfavourable in respect of progression and motivation.

#### *Interaction of the Factual and Methodical Discussion*

Especially in terms of motivation, but also in terms of the concrete comprehensibility of contextual relationships, the close interconnection of technical and methodological parts became obvious. With regard to opportunities in which students can learn about a scientific method, or in which they can exemplarily apply it, indicators for an increased curiosity and/or increased interest were observed. In addition, in such situations, the students were particularly well equipped to grasp the thematic aspects on the level of content that potentially could be explored with the respective method. On the one hand, this can be justified by the combination of procedural and declarative knowledge. On the other hand, the testing of a specialised method, such as the microscopy of pollen of nearby plants, the measurement of climate parameters in the schoolyard, or the interviewing of passers-by on campus, again establishes a relationship between scientific contents and genuine life-world situations. Accordingly, it is not surprising that those phases, which are solely based on the processing of the online modules, do not show comparable effects.

#### *Measures of Guidance*

The role of adequate measures of guidance, which has been emphasized for the success of inquiry-based learning processes by earlier studies (e.g. Lazonder and Harmsen 2016), could also be observed during the W-Seminar. Prompts and heuristics proved very useful for the learner group who had not worked in this way before and to foster students' awareness of when and how to perform certain tasks and actions. Especially in the case of specialised methods, detailed explanations were used to guide the learners step by step towards the correct application of the method. In order to allow students to focus on the contents only, the first interim presentations were scaffolded, i.e. the corresponding Power Point presentations were pre-structured on the basis of individual building blocks. Situations that lacked constraints and scaffolding turned out to be rather hindering for the learning process (for a detailed typology of IBL guidance see Lazonder and Harmsen 2016). In general, different forms of support can be applied dynamically over the course of the seminar, as every phase of the research cycle may require specific strong control measures. However, for certain recurring inquiry skills such as communicating research results, the intensity and specificity of guidance measures can fade out successively, as students improve their competences during the course of the project.

#### *Additional Influencing Factors*

Even though a corporate design for the materials may seem trivial, it proved to be very favourable for the perception of identity and professionalism. Additionally, a learning environment, which is tailored to the perspectives and needs of the students and ascribes the teacher the role of a mentor and learning companion, turned out to be profitable, as it entails a strong learner-orientation. Conversations with the participating students also revealed that framing the concept with the Citizen Science Approach as well as the close exchange with the university, promote the feeling of participating in a superordinate societal task and thereby a sense of responsibility.

## **5 Conclusion**

So far, experience with climate change education has shown that especially the factual and ethical complexity of the field and the perceived spatial and temporal detachment are key concerns. According to research findings, inquiry-based learning seems to be a promising approach to deal with these difficulties, as it fosters (among others) self-directed learning, critical thinking skills, the redesign of scientific misconceptions, local action on global issues, as well as the development of a feeling of proximity and perceived self-efficacy. The Augsburg IBL concept was designed to specifically fit the needs of senior class climate change education. Based on first insights, it seems suitable to achieve its intended goals. Nevertheless, important design principles that should be followed to obtain the desired results could also be identified.

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## 4.2 Beitrag 2: Inquiry-Based Learning on Climate Change in Upper Secondary Education: A Design-Based Approach

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## Article

# Inquiry-Based Learning on Climate Change in Upper Secondary Education: A Design-Based Approach

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**Abstract:** Education is of great importance in the context of climate change, as it can promote pro-environmental behaviour. However, climate change education is accompanied by didactic and pedagogical challenges because, among other reasons, climate change is a complex phenomenon and many people have a psychological distance to the topic. A promising approach to face these challenges is inquiry-based learning (IBL), as several studies show. To date, however, there are barely any empirically tested instructional designs, especially for close-to-science IBL, focusing on climate change. The study presented here therefore addresses the question of how a science propaedeutic seminar for upper secondary schools on the regional implications of climate change should be designed to ensure successful learning processes. Based on the design-based research approach, qualitative research methods (focus group discussions, semi-standardised written teacher surveys, and participant observations) were used to identify target-oriented design guidelines and implementation principles for such seminars. In the seminars, 769 students have so far researched different aspects of climate change in their own regions. The identified design guidelines and implementation principles were further operationalised for teaching practice, so that the research generated both a contribution to theory building and an applicable concept for schools.

**Keywords:** inquiry-based learning; climate change education; climate literacy; design-based research; regional climate change; science propaedeutics



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## 1. Introduction

Climate change represents one of the greatest challenges for humanity in the 21st century. This situation not only requires economic and political measures but also the climate-literate behaviour of individuals and social groups. Thus, Climate Change Education (CCE), aiming for climate-literate people who are able and willing to face climate change via mitigation and adaptation, has been a central issue in the social and educational sciences in recent years. Whereas the complex mosaic of climate-related education and communication processes still needs further investigation (especially among young people; see [1]), related research so far was able to distil out not only the central challenges but also important criteria to pursue the intended goal of climate literacy. In the following, we will discuss the suitability of the Inquiry-Based Learning (IBL) approach to face key issues of CCE. We further show how IBL in the context of CCE can be brought to fruition at schools by applying particular design principles.

### 1.1. Climate Literacy

The overall goal in CCE can be described with the multidimensional construct of climate literacy [2,3]. According to Azevedo and Marques [3] (p. 422), “to be climate literate, one needs to:

- have some knowledge of climate science, in its content, procedural and epistemic components,

- master in some degree a number of competences that allow accessing and assessing relevant information about this theme, as well as communicate it in a meaningful way,
- reveal a set of attitudes that lead to one's contribution to the conception and/or implementation of adaptation and mitigation strategies."

As especially the first two aspects imply, climate literacy can be considered as a specific context of application for science literacy [2,3], which is defined by the competence to "explain phenomena scientifically [,] evaluate and design scientific enquiry [and] interpret data and evidence scientifically" [4] (p. 21).

While this concept of climate literacy explicitly considers the importance of climate-related attitudes, it also underlines the major role of science- and research-related competences. Therefore, learning processes in CCE should at best address both of them.

### *1.2. Important Challenges in Climate Change Education*

However, these goals are not easy to achieve, as there are some major challenges in CCE: from both a factual and ethical perspective, climate change represents a complex issue [5]. Not only is the climate system itself technically complex [6], but so is the discourse about the topic, which is characterised by the interconnection of various aspects like ecological goals, economic interests, cultural orientations, social norms, and political decisions [7]. Consequently, learning processes should include opportunities to develop competences for dealing with complex topics. Given this complexity, it is also not surprising that international research in the field of conceptual change has shown that students often have incorrect, highly persistent conceptions of climate change—especially concerning the causes of climate change and potential solution approaches [8]. For example, many children and teenagers mistakenly confuse the ozone hole phenomenon with the anthropological greenhouse effect or assume that a confined greenhouse gas layer exists in the higher atmosphere [8–11]. On the whole, research shows that confrontation and active work with misconceptions in lessons is more effective than ignoring them [8,10]. This appears even more important against the background of the representation of climate change in the media or in political debates where we can find plenty of controversial information, and also "fake news", particularly concerning the causes of climate change. Here especially, strategies to practice critical reflection of (sources of) information should be applied [12,13].

However, even if a more-or-less differentiated knowledge about climate change does exist—which is the case, for instance, in Central European societies [14]—a discrepancy between knowledge or awareness of climate change and personal attitudes or even action can often be observed [15,16]. This is especially true for young people [17]. Factors to elucidate this discrepancy are diverse: on a personal level, for instance knowledge, values and attitudes, interests and perceived self-efficacy play important roles, whereas situational factors like available infrastructure, economic circumstances, or social context also have considerable influence [14]. While this illustrates that knowledge alone does not inevitably lead to climate-literate behaviour, studies show that it is nevertheless an essential precondition for it [18].

Aside from other factors, one explanation for the described knowledge–action gap is that climate change is often perceived as a rather abstract phenomenon, especially in Western countries [19]. Many individuals think that their opportunities for action are very limited and that they cannot make a difference. This can at least be partly explained by so-called psychological distancing: while many people do accept the fact that climate change is happening, they often ascribe it to other parts of the world and a distant future [14]. Especially adolescents tend to consider climate change irrelevant to their immediate everyday realities [20]. Consequently, creating psychological proximity is not only deemed to be a potential factor for awareness of and concern about climate change [19,21–23], but also a strong relevance to one's everyday life in general supports the communication of climate issues among adolescents [14,24].

### 1.3. Inquiry-Based Learning as a Promising Approach for Climate Change Education

Overall, the challenges described above ask for adequate educational measures to counteract them. While there is still research to be done, studies were already able to outline a set of key principles for environmental and climate change education. For instance, in a systematic literature review, Monroe et al. [25] (p. 791) identified the following: both “(1) focusing on personally relevant and meaningful information and (2) using active and engaging teaching methods” are most common in environmental education, while particularly for CCE, “(1) engaging in deliberative discussions, (2) interacting with scientists, (3) addressing misconceptions, and (4) implementing school or community projects” were identified as the central principles to foster climate literacy. Consequently, educational conceptions should at best encompass all of them to be potentially fruitful.

One promising approach to adapt these principles is Inquiry-Based Learning (IBL). This term refers to educational work-forms, which serve the search for and finding of knowledge that is new (at least) to the learner, and which happen analogous to the characteristics of scientific knowledge production regarding attitude, methods, and systematic proceeding [26–28].

Corresponding work-forms bring along the potential to realise exactly Monroe et al.’s [25] above-mentioned four principles for CCE because IBL can be implemented in comprehensive school projects. There, reflection and classroom discussions can be complemented by interaction with scientists and through students’ intense scientific activities on individual research questions, they can be confronted with their own misconceptions.

Indeed, research shows that IBL is capable of addressing competences that are considered central components of scientific literacy and/or such that contribute to overcome the aforementioned challenges in CCE:

According to different authors [29–31], IBL can help to develop an array of so-called 21st century skills (e.g., creativity, innovativeness, collaboration and communication, critical thinking, problem-solving, or decision-making) in general. In addition, relevant empirical research shows a broad spectrum of encouraging insights with regard to specific goal dimensions of climate literacy. For instance, various studies were able to point out positive effects of IBL on critical-thinking skills (e.g., [31–34]). Duran and Dökme [35] could prove a better support of critical thinking via IBL in comparison with conventional approaches. Such skills are especially useful with regard to the formerly described media and political discourse about climate change as they help, for example, to uncover simple truths.

In relevant studies, IBL was able to foster conceptual change in general [36] and to improve students’ perception of the greenhouse effect in particular [37].

Several studies observed increased motivation of learners via IBL (e.g., [38,39]), whereas some of them even found positive effects on the feeling of self-efficacy [40,41]. These findings are of particular importance, as feelings of powerlessness and hopelessness towards climate change represent a great challenge in CCE [14,42,43]. In contrast to that, motivation and self-efficacy represent crucial prerequisites for sustainable action [44–46].

Actively experiencing research by learners may promote a better understanding of scientific concepts [47,48], which Klein [49], Mao et al. [50], and Chang and Mao [51] have particularly shown among the Earth sciences. More specifically, Namdar [52] conceived IBL on the subject of global climate change for future teachers, who thereby could significantly enhance their understanding of global climate change. Additionally, IBL can increase scientific process skills [53]. Arieska Putri et al. [54] could even show a direct effect of IBL on scientific literacy.

This is not very surprising in that science literacy (and, more context-specifically, also the initially described climate literacy) is very strongly related to the desired key competences, which are usually addressed especially by close-to-science IBL formats (for a detailed distinction of different IBL formats see for example [55]); Gess et al. [56] (p. 79) describe the intended “research competence” as a combination of receptive research skills (i.e., information literacy, statistical literacy, and critical thinking) and productive research skills, which include cognitive competences (e.g., knowledge about research

processes and methods, generation of hypotheses, or data analysis), affective-motivational competences (e.g., research-related self-efficacy or tolerance of uncertainty and ambiguity), and the social competence of cooperation in a learning community. According to them, involvement in IBL should additionally foster a so-called research attitude, which comprises a reflexive distance, epistemic curiosity—i.e., an intrinsically motivated tendency to gain new insights [57]—and differentiated epistemological beliefs, in the sense of personal assumptions about the nature of knowledge and the process of knowledge creation [58].

Wiemer [59] argues that the achievement of such competences is facilitated by some particular learning and reflection processes in IBL, such as dealing with uncertain knowledge and undetermined results, experiencing and communicating basic scientific values and attitudes in a scientific community, or the transition from an everyday perspective to a scientific perspective and development of an own reasonable and justifiable position.

In order to operationalise IBL in such strongly science-oriented forms, IBL conceptions should be characterised by a set of design guidelines described in literature:

- An extensive timeframe, in which a whole research cycle can be realised [60–64],
- Learning processes that build on research questions that are not pre-determined by the teacher but self-determined by the students' based on their individual interests [26,61,65,66],
- Complex content that can be addressed from different scientific perspectives [26,67],
- Extensive application of methods commonly used within a scientific discipline [68], at best with the opportunity to choose from a broad methodical repertoire [67],
- Aiming at research findings that go beyond the individual learning processes and might be of common (scientific) interest [69],
- Critical reflection and transparent, comprehensible communication of research results and methods [26,60,65,70],
- High amounts of self-directedness and self-responsibility over the whole research process [26,62,71–73],
- Various opportunities to experience research as a social, cooperative process [26,48,74],
- Organisational and content-related openness [26,67],
- Authentic problems that allow the embedding of learning processes into the complex context of everyday realities [26].

Given this empirical and theoretical background, because of its inherent characteristics IBL appears to be a suitable approach for fostering climate literacy, if extensive science-oriented formats are applied.

#### 1.4. Implementation of Inquiry-Based Learning at Schools

Unfortunately, it is precisely these close-to-science formats that are most rarely applied in school contexts (one exception is the “FLidO” project, which is currently under development—see [75,76]). This can be partly explained by the fact that IBL, at least in Germany, has a longer tradition as a university-didactic approach and therefore the scientific discourse is still predominantly located in this context (see for example [26,74,77–84]). Besides that, literature describes various challenges in IBL (see for instance [65,85–88]), which doubtlessly represent even more limiting factors regarding school education. Our own practical experiences at schools, as well as the considerable feedback from teachers, show that one of the greatest hindrances is the rigid and narrow timeframe provided by school curricula, which usually allow neither the accomplishment of a whole authentic research cycle nor activities like field research that deviate extensively from the usual “portioned” lesson structure. Moreover, strongly science-oriented IBL comes along with increased content-related, methodical, and intellectual complexity and difficulty, which represents unaccustomed challenges not only for students but also for teachers. Teacher education tends to have a limited research orientation. Against this background, many teachers have little experience in conducting and supervising research projects. Many teachers are uncertain about the collection and analysis of data, and also about subject-specific concepts, theoretical backgrounds, and the nature of science, as well as research ethics.

As a result, especially in geography education, IBL often focuses on experimental work-forms (see for example [89–94]), as such approaches might usually be not too time-consuming and because the clear structure is better controllable and manageable. Correspondingly, insights on effects and preconditions of IBL are predominantly derived from concepts within the domain of natural science education, while those from the humanities or social sciences are rather seldom (see for example [68,95]).

Many school projects and other forms of open education give students and teachers the freedom to determine for themselves the topics to be covered. This is a great advantage especially when, for example, climate change is not included in the existing curricula. The so-called W-Seminar at Bavarian high schools (Gymnasien) provides an especially suitable framework for such project-oriented teaching. It represents a science-propaedeutic seminar (“W” abbreviates “wissenschaftspröpädeutisch”, which translates as “science propaedeutic”) format in senior classes (grades 11 and 12, students aged 15–18), on the threshold between school and university. Within the period of 1.5 years, students are meant to conduct research on an individual topic and write a scientific seminar paper about it. Combined with IBL, this format provides the potential for students to learn “in their own backyards” and to create psychological proximity, to link different spatial and temporal scale levels, and to foster conceptual change. Unfortunately, while there are official guidelines for planning and exerting a W-Seminar [96–100], targeted considerations about how to implement close-to-science IBL in this framework do not exist at all. So, approaches in the particular context of CCE cannot be built on existing templates. Consequently, we aim to fill this gap with our research.

### 1.5. Purpose of the Study and Research Questions

As shown above, IBL brings potentials for CCE when conceived in close-to-science formats. Nevertheless, the realisation of authentic, science-oriented propaedeutics according to the IBL approach in school contexts is a big challenge and, therefore, concrete conceptions are rare. At the same time, (domain-specific) didactic theory is still lacking specific knowledge on the school-based application of IBL in general and its application particularly in CCE contexts. Especially for the school context, transferable how-to guidelines for close-to-science IBL are barely available (for the university context see [64,81]). Therefore, our research aims at the identification of design principles for the realisation of close-to-science IBL environments in the context of climate change at upper secondary schools to address the potentials and challenges outlined in Chapter 1. Hence, our research question is:

**RQ1:** *How should a science propaedeutic seminar on regional implications of climate change be conceptualised in upper secondary schools to support successful learning processes in a close-to-science IBL approach?*

To create a context-specific theoretical framework for the desired learning environment, research sub-question 1a is:

**RQ1a:** *Which design guidelines and implementation principles can be identified for the [successful] design of close-to-science IBL on regional implications of climate change in upper secondary schools?*

To apply this theoretical framework for the design of a concrete learning environment as a practical research output, research sub-question 1b is:

**RQ1b:** *How can the identified principles be operationalised for the target group of upper secondary school students in the conception of a learning environment?*

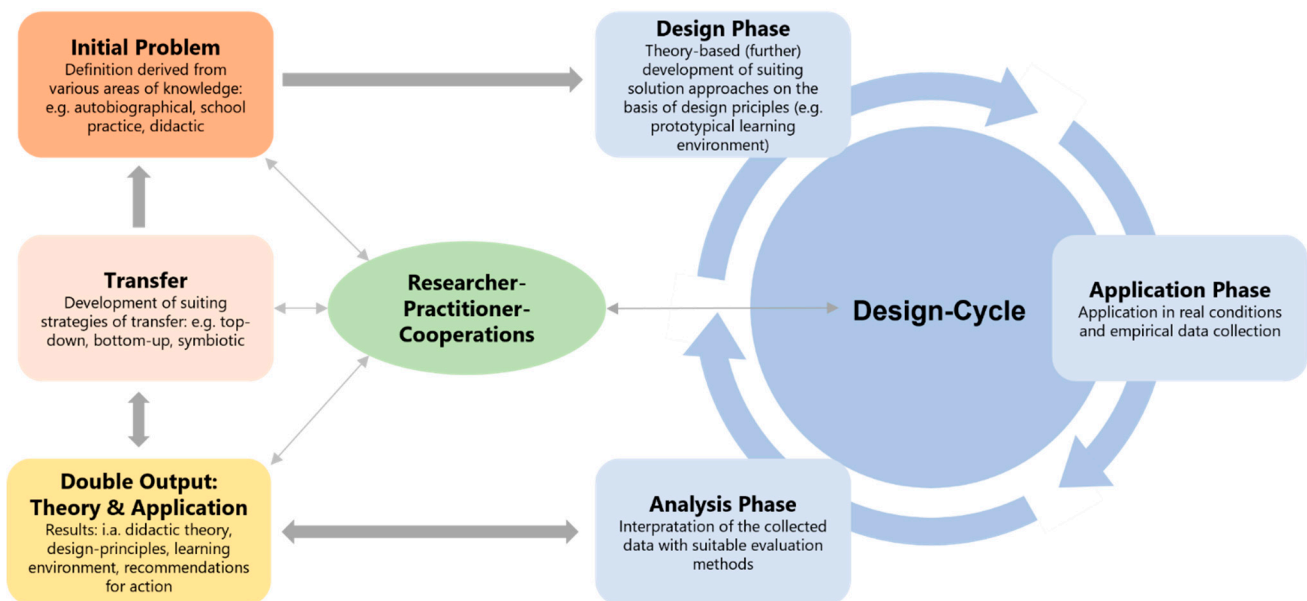
## 2. Methods

### 2.1. Methodological Framework: Design-Based Research

These research questions focus on a so-called theory-practice problem [101]. Therefore, we address these issues by implementing design-based research (DBR) as a methodological framework. As an application-oriented basic research approach, DBR is particularly appropriate for such theory-practice problems [101–104] because it combines empirical

educational research and theory building with the development of learning environments in practical contexts [103,105,106].

We follow a typical DBR research structure that consists of characteristic core elements (see Figure 1). Starting from the underlying problem, an initial design of the learning environment must be developed. As typical in DBR, this was based on a researcher-practitioner cooperation: together with a teacher, we developed a concept for a W-Seminar on the regional implications of climate change. For this purpose, we developed design principles that are central to the DBR processes. These are considered to be context-specific design criteria on different levels of concretisation (for a detailed definition see [104]).



**Figure 1.** Schematic structure of a DBR research process (adapted and translated from [104]).

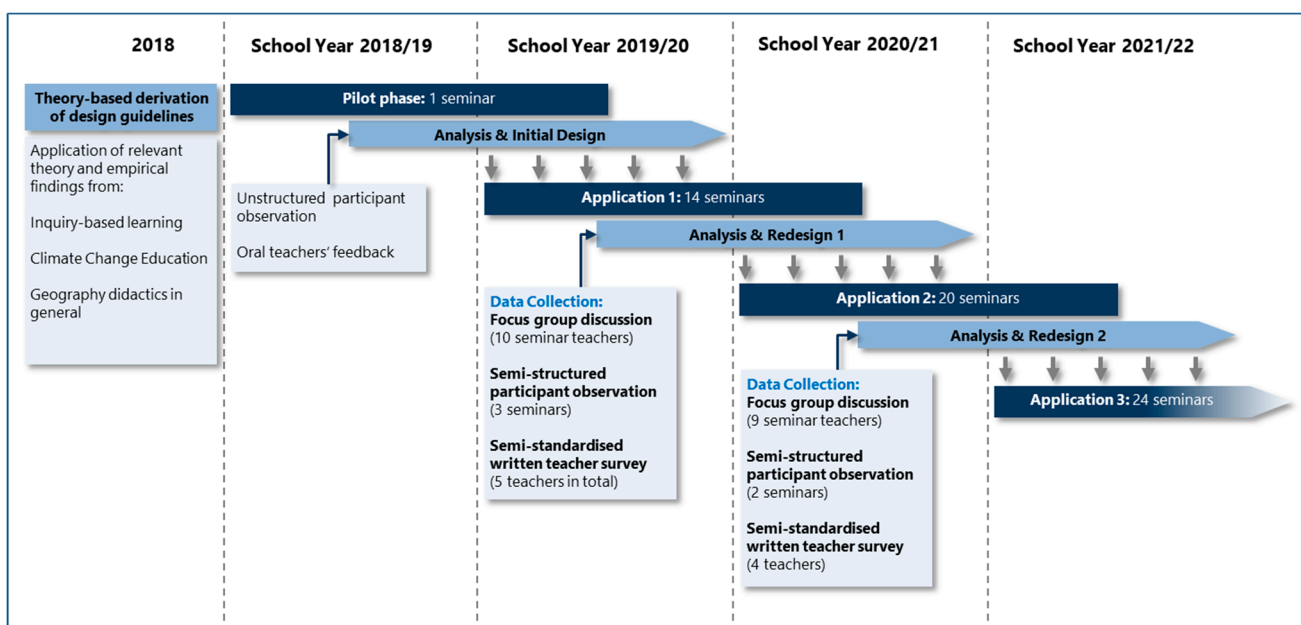
In a first step, we derived a set of superordinate “design guidelines” from theoretical and empirical research literature to comprehensively implement science-oriented IBL and bring its potentials regarding CCE to fruition (see Chapter 1). These theory-based design guidelines were set as a baseline for the subsequent research process and therefore not subjected to further modification. Based on them, we developed a structure for the seminar concept by applying the logic of a prototypical scientific research cycle to the organisational framework of the W-Seminar format. In a second step, for the individual phases of the conception we derived further design principles on the specific levels of operationalisation from the superordinate design guidelines; in doing so, design guidelines were differentiated into “implementation principles” (i.e., influencing factors at key points that are likely to be relevant in the design of the learning environment). These in turn were translated into a “target-group-specific operationalisation”, which consists of a finely structured set of individual didactic-methodical decisions. As a concrete practice output, these three levels of design principles can then be realised as detailed tasks, methods, materials, and the like. Table 1 represents an exemplary illustration of the systematic approach in the DBR process, as described above.

In a third conceptual step of the initial design, we created a pilot version of the learning environment based on this catalogue of theory-driven design principles, applied it in the pilot W-Seminar and evaluated it via unstructured participant observation and oral teacher feedback (see Figure 2). Therefore, researchers intensively accompanied the individual sessions of the entire seminar (except a few single sessions that were spent on classroom tests or organisational issues) to detect any aspects that appeared relevant. In addition, our cooperating teacher gave us regular feedback on her observations over the whole seminar

process. These practical experiences allowed us to identify the first central requirements for lesson practice and to integrate them into the initial design.

**Table 1.** Examples for the different operationalisation levels of design principles.

Design Guidelines (Example)	Implementation Principles (Examples)	Target Group-Specific Operationalisation (Examples)	Concrete Practice Output (Examples)
	IBL should provide occasions that allow students to find individual fields of interest for their research projects	[ ... ]	[ ... ]
Learning processes in IBL should build on research questions that are not predetermined by the teacher but self-determined by the students based on their individual interests	IBL should include learning steps which enable students to formulate individual research questions based on their interests	Provision of central quality criteria for adequate research questions	<ul style="list-style-type: none"> <li>Worksheet “Criteria for a good research question” + complementary materials</li> <li>Worksheet “Different types of research questions”</li> </ul>
		Confinement and concretisation of individual thematic contexts	<ul style="list-style-type: none"> <li>Worksheet “Steps on the way to a research question” + sample</li> </ul>
		[ ... ]	[ ... ]
	IBL should include learning steps which enable students to develop individual methodical research designs based on their interests	[ ... ]	[ ... ]
	[ ... ]		
[ ... ]			



**Figure 2.** Concretised structure of the DBR process (own representation).

Finally, we subjected the completed initial design to two main design cycles. In total, 34 teachers and 433 students participated in the 34 seminars that were included in these two main cycles (14 seminars in cycle 1 and 20 seminars in cycle 2). In total, together with cycle 3, 769 students were part of the seminar. Teachers (mainly in the public school system) could voluntarily apply with their classes for the seminar concept, which was promoted via the central institution for teacher training and professionalisation in Bavaria. The offer should address every interested teacher—in doing so, we were able to include teachers with diverse backgrounds, such as different experiences in science teaching and CCE, different subject combinations (in Germany, teachers at secondary schools usually teach two or more core subjects), or different overall teaching experiences. This enabled us to assess multiple needs during the DBR process and to address them with our conception. The fundament of the application in these two main cycles was a comprehensive in-detail teachers' manual, including lesson schedules, planning documents, templates, learning materials, theoretical backgrounds, and additional information sources, which was handed out to the teachers in the respective latest version (a current version is available as a preprint; see [107]). To make sure the conception would be exerted in the intended way, we developed a three-day teacher training session, in which our cooperating teachers participated in advance of the respective W-Seminar. Additionally, participating teachers were given the opportunity to contact us via a weekly telephone consultation hour. This showed that teachers, in sum, were getting along very well with the manual and the basics conveyed in the teacher training—questions mainly focused on organisational issues like lending research equipment from the university. In all schools, the same teacher was teaching the same students over the whole course of a seminar.

The seminars of each generation started at the beginning of a new school year in September. As the total duration of a W-Seminar is 1.5 years, this created an overlap of half a year in the pilot phase and the two main research cycles. Consequently, the data analysis and redesign had to be timed to gain a head start for the implementation of the results into the next cycle. This means that while the respective new seminar generation had already started based on the redesigned conception of the first seminar phases, data analysis for the redesign of the advanced seminar phases was still carried out (see Figure 2). The insights gathered from the main cycles 1 and 2 were finally implemented in "Application 3", which is currently being carried out at 24 schools (24 teachers and 336 students) but not subjected to the above-mentioned research questions.

The goal of this DBR-typical iterative approach was to investigate the suitability of the identified design principles for supporting different facets of students' learning processes during IBL. In doing so, both design principles and the resulting learning environment could be optimised and further developed successively through the iterations of the DBR process.

## 2.2. Data Collection and Analysis

With our research, we aimed to consider as many aspects and influencing factors regarding successful learning processes as possible. This open, explorative character requires a holistic in-detail assessment of the learning processes in a natural application context rather than controlled conditions [108–110]. Therefore, we chose to employ methods from the qualitative paradigm.

As we wanted to include both the teachers' perspective and the researchers' perspective into the assessment of our research questions, we applied data- and method-related triangulation [110,111] by employing the following methods.

### 2.2.1. Focus Group Discussions

As one approach, we referred to the experiences and observations of cooperating teachers who applied our seminar concept during the respective main design cycles. For this purpose, we applied focus group discussions, in which the group members discuss a selected topic and mutually react to their considerations with, for example, consent, denial, or

complementing remarks [109,110,112]. This was particularly necessary to draw as precisely as possible an image of the important aspects for the assessment of our research question. To structure and focus the discussion, we concentrated on the following perspectives:

- Evaluation of the overall process structure,
- Selected aspects of specific seminar phases (e.g., comprehensibility of particular learning materials),
- Evaluation of student interest and motivation over the course of the learning process and assumptions about influencing factors,
- Evaluation of the practical suitability of different seminar units and learning tasks,
- Experiences with implemented guidance measures,
- Experiences and challenges regarding the specific teacher role.

In design cycle 1, we had 10 cooperating teachers participating in the discussion, and 9 teachers in design cycle 2. The focus group discussions were recorded on video and transcribed for further processing.

### 2.2.2. Semi-Standardised Written Teacher Survey

Additionally, we employed semi-standardized questionnaires [109,113,114]. In advance of the focus group discussions in research cycle 1, teachers were asked to share their experiences with the seminar conception regarding a set of selected questions. Five teachers answered the questions, which were, for example:

- “In your opinion, what went well in your W-seminar in phase XY, and what did not?”
- “In what way do you consider the structure of phase XY-regarding the internal structure of the individual lessons and the sequence of sessions within the phase-to be effective, and in what way not?”
- “At which points do you consider the guidance measures for students provided in the concept as appropriate, and at which points not (e.g., work materials, learning tasks, didactic-methodical decisions, teaching impulses)?”
- “How do you determine your assessment and what suggestions can you think of to make the guidance even more effective?”

For a more detailed assessment of single seminar lessons, especially within the emergence and planning phase, teachers were asked to answer questions on specific aspects of their impressions and observations during the learning processes after each lesson. These questionnaires were answered by four teachers each in the first and second design cycles. Exemplary items from the questionnaire are:

- “At which points of this session could the intended competence goals be achieved?”
- “How would you estimate the motivation of your students during this session and by what was it influenced from your point of view?”
- “At which points did you as a teacher get along well with the conception of this session, and where less so? What are possible reasons for that?”
- “In your opinion, how clear was the aim of the session’s individual learning steps to your students?”

### 2.2.3. Participant Observation

We complemented the teachers’ perspective by semi-structured participant observation [108–110,114]. During various lessons throughout the seminar application, a researcher was present in the classroom and followed the events. The lessons to be observed were chosen based on the insights of the pilot cycle. We included seminar sessions that were most likely to represent challenging steps of the IBL process, and therefore were most likely to provide promising insights in the observation (this applies, for example, to the classroom sessions of phase B, all the lessons of phase C, or the fixed-point sessions of phase D—see Table 3). The researcher’s observations were based on a semi-structured observation sheet, which focused on the assessment of existing design principles but also allowed unexpected observations. Perspectives of the observation sheet were, for example, observable outcomes

of individual learning tasks, indications of students' comprehension problems, visible influences of activities on students' motivation, interaction between teacher and students, or the suitability of the structure of learning steps. During the observations, the researcher only interacted with students on a few occasions (e.g., small talk when observing students working in groups, or organisational issues like how to use university infrastructure, such as online public access library catalogues). This procedure was applied to three selected seminars in the first main cycle and two seminars in the second main cycle. The observation sheets were digitalised for further processing.

#### 2.2.4. Data Analysis

The data gathered through all of the above-mentioned methodical approaches were finally analysed via qualitative content analysis. More specifically, we applied a combination of thematic and evaluative qualitative content analysis [115]. In a first step, the existing design principles were applied to the data as deductive analysis categories to identify those of the design principles that seemed to be most relevant during the learning processes (e.g., by appearing very frequently or particularly emphasized in the data). Additionally, inductive categories were generated from the material (i.e., scattered observations that are thematically related and can therefore be summarized in a new category). In a second step, the design principles (respectively their target-group-specific operationalisations) that could be identified as relevant by this means were evaluated to find out if they exerted a positive or negative influence on the learning processes. From the results of these analyses, we drew conclusions about the initially derived design principles (respectively their operationalised implementations) that have an observable impact on the learning processes, and about the way in which they foster the intended learning outcome. Based on these insights, we refined and complemented the set of design principles and applied them for the redesign of the learning environment as a starting point for the subsequent research cycle.

### 3. Results

Based on the initial literature research, we were able to identify a set of superordinate design guidelines for close-to-science IBL at schools. As mentioned above, they were applied as a baseline for the subsequent research process. We differentiated this set of design guidelines down on all levels of operationalisation (see Table 1) as a basis for the concrete design of our learning environment. Over the course of the pilot phase and the two main research cycles, we reworked and adjusted the catalogue of underlying design principles. An overview of the final design guidelines and implementation principles is given in Table 2.

**Table 2.** Theory-based design guidelines and derived implementation principles for Inquiry-Based Learning in the context of Climate Change Education.

Design Guidelines	Implementation Principles
(1) IBL conceptions should provide an extensive timeframe in which a whole research cycle can be realised.	<ul style="list-style-type: none"> <li>(a) IBL conceptions should contain a start-up phase to introduce students into IBL and to give an overview of the following learning process.</li> <li>(b) IBL conceptions should contain a phase that allows students to dive into the theoretical and empirical basics of the respective learning context.</li> <li>(c) IBL conceptions should contain a phase that allows students to develop their own research questions, research methodical designs, and chronological research plans based on their individual interests.</li> <li>(d) IBL conceptions should contain a phase that allows students extensive field research activities.</li> <li>(e) IBL conceptions should contain a phase that allows students to present their research in a written and oral form.</li> </ul>
(2) Learning processes in IBL should build on research questions that are not predetermined by the teacher but self-determined by the students based on their individual interests.	<ul style="list-style-type: none"> <li>(a) IBL should provide occasions that allow students to find individual fields of interest for their research projects.</li> <li>(b) IBL should include learning steps that enable students to formulate individual research questions based on their interests.</li> <li>(c) IBL should include learning steps that enable students to develop individual methodical research designs based on their interests.</li> <li>(d) IBL should include learning steps to evaluate and refine students' individual research questions and methodical research designs.</li> </ul>
(3) IBL should integrate complex content that can be addressed from different scientific perspectives.	<ul style="list-style-type: none"> <li>(a) The content in IBL learning environments should at best be chosen to allow addressing it from the perspectives of natural sciences, social sciences, and humanities.</li> <li>(b) The content in IBL learning environments should have an adequate level of complexity that allows and requires it to be successively permeated by students' research activities.</li> </ul>
(4) In IBL, methods commonly used within a scientific discipline should be extensively applied, at best with the opportunity to choose from a broad methodical repertoire.	<ul style="list-style-type: none"> <li>(a) IBL should provide a broad methodical repertoire from the respective scientific discipline.</li> <li>(b) In IBL, methods for data collection commonly used within a scientific discipline should be extensively applied.</li> <li>(c) In IBL, methods for data analysis commonly used within a scientific discipline should be applied.</li> </ul>
(5) IBL should at best aim at research findings that go beyond the individual learning processes and might be of common (scientific) interest.	<ul style="list-style-type: none"> <li>(a) Research questions in IBL should at best aim at findings that are not only new for the learners themselves.</li> <li>(b) Written and oral communication of students' research in IBL should at best highlight potentially new insights gathered through students' research processes.</li> </ul>

Table 2. Cont.

Design Guidelines	Implementation Principles
(6) IBL should explicitly include critical reflection and transparent, comprehensible communication of research results and methods.	<ul style="list-style-type: none"> <li>(a) IBL should include various occasions for students to reflect critically on their individual knowledge generation processes.</li> <li>(b) IBL should provide various occasions for students to reflect critically on the information sources used in their individual research projects.</li> <li>(c) IBL should provide various occasions for students to reflect critically on the individually applied research methods and their limitations.</li> <li>(d) IBL should require students to communicate their individual research results and methods in a transparent, comprehensive manner, including given limitations.</li> </ul>
(7) IBL should be characterised by high amounts of self-directedness and self-responsibility over the whole research process.	<ul style="list-style-type: none"> <li>(a) In IBL, students should be enabled to self-direct their individual data collection and analysis processes.</li> <li>(b) In IBL, students should be enabled to self-direct the written communication of their individual research projects.</li> <li>(c) In IBL, students should be responsible for the planning of their individual research processes to an adequate extent.</li> <li>(d) In IBL, students should be responsible for the success of their individual research processes to an adequate extent.</li> <li>(e) In IBL, students should be responsible for the quality of their individual research results to an adequate extent.</li> <li>(f) In IBL, students should be enabled to self-direct their acquisition of basic knowledge about the given thematic context to an adequate extent.</li> </ul>
(8) IBL conceptions should create various opportunities to experience research as a social, cooperative process.	<ul style="list-style-type: none"> <li>(a) IBL should include cooperative learning activities where appropriate.</li> <li>(b) IBL should include various occasions for common and mutual reflection.</li> <li>(c) IBL should include constructive peer-review and peer-feedback within the learning group where appropriate.</li> </ul>
(9) IBL should be characterised by organisational and content-related openness.	<ul style="list-style-type: none"> <li>(a) In IBL, deviations from the usual curriculum-based lesson structure should be possible where necessary and purposeful.</li> <li>(b) In IBL, both a concrete content-area should be defined, and freedom for students to choose from this area should be given.</li> </ul>
(10) IBL should focus on authentic problems that allow the embedding of learning processes into the complex context of everyday realities.	<ul style="list-style-type: none"> <li>(a) Students' research in IBL should at best address questions that are meaningful for real life.</li> <li>(b) Students' research in IBL should at best be carried out on a local to regional scale level.</li> <li>(c) IBL should provide support for students to relate their research interest to their own everyday realities.</li> </ul>
(11) IBL should integrate various occasions to support conceptual change.	<ul style="list-style-type: none"> <li>(a) IBL should include occasions to make students' misconceptions visible for the teacher.</li> <li>(b) IBL should provide occasions for students to experience cognitive conflicts between scientific conceptions and their own mental conceptions.</li> <li>(c) IBL should provide occasions for students to reconstruct their individual mental conceptions.</li> </ul>

Table 2. Cont.

Design Guidelines	Implementation Principles
(12) IBL should support students to intensively immerse into and research the factual basics of the respective context.	<ul style="list-style-type: none"> <li>(a) IBL should provide an adequate timeframe to enable students' intense immersion into the factual basics of the respective context.</li> <li>(b) IBL should provide adequate information sources and learning materials to support students' engagement with the factual basics of the respective learning context.</li> <li>(c) IBL should include occasions to evaluate students' learning outcomes when engaging with the factual basics of the respective context.</li> </ul>
(13) IBL should draw on targeted insights into authentic science (in the sense of science carried out by professionals in the respective field).	<ul style="list-style-type: none"> <li>(a) IBL should aim to clarify the process and means of knowledge production in the respective scientific discipline.</li> <li>(b) IBL should implement examples to illustrate core characteristics and concepts of science.</li> <li>(c) IBL should include insights into potentials and limitations of genuine science.</li> <li>(d) IBL should include occasions to reflect on epistemological beliefs.</li> </ul>
(14) IBL should integrate activities to practice systematic scientific procedures.	<ul style="list-style-type: none"> <li>(a) IBL should integrate activities to practice literature research.</li> <li>(b) IBL should integrate activities to practice the development of research questions and methodical designs.</li> <li>(c) IBL should integrate activities to practice systematic data collection.</li> <li>(d) IBL should integrate activities to practice systematic data analysis.</li> <li>(e) IBL should integrate activities to practice the written and oral communication of research projects.</li> </ul>
(15) IBL conceptions should provide an adequate amount of guidance for the students.	<ul style="list-style-type: none"> <li>(a) IBL conceptions should provide adequate guidance on the level of content knowledge and cognitive competences.</li> <li>(b) IBL conceptions should provide adequate guidance on the level of research methods and procedural research skills.</li> <li>(c) IBL conceptions should provide adequate guidance on the level of emotional and motivational aspects.</li> <li>(d) IBL conceptions should provide adequate guidance on the level of organisation.</li> </ul>
(16) IBL conceptions should provide an adequate amount of support for the teachers to guide the students through their learning processes.	<ul style="list-style-type: none"> <li>(a) IBL conceptions should support teachers to convey content knowledge.</li> <li>(b) IBL conceptions should support teachers to convey methodical knowledge and procedural research skills.</li> <li>(c) IBL conceptions should support teachers to provide students with motivational support.</li> <li>(d) IBL conceptions should support teachers to provide students with organisational guidance.</li> <li>(e) IBL conceptions should support teachers to moderate reflection processes among the students.</li> <li>(f) IBL conceptions should support teachers to provide students with situational ad-hoc support over the whole learning process.</li> </ul>

Based on them, we created and successively redesigned the learning environment, which incorporates finely structured didactic-methodical decisions on the level of target-group-specific operationalisation, as well as concrete tasks, methods, and materials. A summary overview of the final structure of the learning environment is given in Table 3: The first column shows the chronological structure of the seminar phases and individual sessions. The second column provides short descriptions of the sessions' central contents, which at the same time represent the target-group-specific operationalisation (see Table 1) of the implementation principles that come to fruition in the respective seminar sessions.

The underlying implementation principles, in turn, are depicted in the right column of the table. For example, the design guideline 2b (“IBL should include learning steps that enable students to formulate individual research questions based on their interests.”) is realised via the provision of central quality criteria for adequate research questions in session C4 of the seminar concept.

**Table 3.** Final operationalisation structure of the learning environment and underlying implementation principles.

	Target-Group-Specific Operationalisation	Underlying Implementation Principles
	<p style="text-align: center;"><b>Phase A</b> <b>Seminar Start</b></p> <p>1 Session (90 min), 1 Brief excursion (90 min or more)</p> <p style="text-align: center;"><b>2 weeks in total</b></p>	<p>Applying to whole phase: 1a, 3a</p>
A1	<ul style="list-style-type: none"> <li>• Introduction to the seminar concept and preview on the IBL approach.</li> <li>• Students’ first encounter with concepts of “research” and “science” and formulation of a working definition.</li> <li>• Brainstorming of previous knowledge about climate change.</li> <li>• Brainstorming of interrelations between the global climate change phenomenon and regional aspects which can be observed by the students.</li> </ul>	10b, 11a, 11c, 13a
A2	<ul style="list-style-type: none"> <li>• Brief excursion in the students’ home region based on the “jigsaw technique”.</li> <li>• Exemplary application of authentic research methods (measurement of climate elements with the “senseBox” system, observation of climate-related behaviour, survey among passers-by on climate-relevant aspects, online analysis of bark beetle data) to inquire selected implications of climate change on a regional scale (in “expert groups”).</li> <li>• Mutual presentation and common reflection of the applied research methods and gathered insights in “home groups”.</li> <li>• Considerations about connections between the abstract global and the visible regional scale of climate-related phenomena.</li> </ul>	4b, 8a, 8b, 9a, 10a, 10b, 13a, 13b, 14c, 15b, 16b
	<p style="text-align: center;"><b>Phase B</b> <b>Diving into the Matter</b></p> <p>Five sessions (90 min each) over the course of at least 6 weeks, + self-directed work at home in between the sessions</p> <p style="text-align: center;"><b>6–8 weeks in total</b></p>	<p>Applying to whole phase: 1b, 3a, 3b, 5a, 9b, 12a, 12b, 15a, 16a</p>
B1	<ul style="list-style-type: none"> <li>• Reflection and postprocessing of A2.</li> <li>• Overview over Phase B and introduction to the e-learning platform “Onlinekurslabor”.</li> <li>• Beginning of elaboration of the causes and functionality of global climate change via interactive learning modules (Basic Module 1).</li> </ul>	6c, 8b, 10c, 11a, 11b, 11c, 13a, 16e

Table 3. Cont.

	Target-Group-Specific Operationalisation	Underlying Implementation Principles
<b>Homework</b>	<ul style="list-style-type: none"> <li>Self-directed elaboration of the causes and functionality of global climate change via interactive learning modules (Basic Module 1).</li> </ul>	7f, 9a, 11b, 11c, 13a
<b>B2</b>	<ul style="list-style-type: none"> <li>Consolidation of knowledge about the causes and functionality of global climate change in plenary session:               <ul style="list-style-type: none"> <li>Classroom quiz about scientific basics of climate change,</li> <li>Role play: Discussion between scientific common sense and climate change deniers.</li> </ul> </li> <li>Beginning of elaboration of the global and regional effects of climate change via interactive learning modules (Basic Module 2).</li> </ul>	8b, 11a, 11b, 11c, 12c, 13a, 13d, 16e
<b>Homework</b>	<ul style="list-style-type: none"> <li>Self-directed elaboration of the global and regional effects of climate change via interactive learning modules (Basic Module 2).</li> </ul>	7f, 9a, 10b, 11b, 11c, 13a, 13b, 13c
<b>B3</b>	<ul style="list-style-type: none"> <li>Consolidation of knowledge about the global and regional effects of climate change in plenary session:               <ul style="list-style-type: none"> <li>Reflection of an interview with a climate researcher about regional effects in Germany,</li> <li>Reflection of regional implications of climate change depicted in the IPCC report,</li> <li>Thematic clustering of the already visible effects of climate change in Bavaria.</li> </ul> </li> <li>Beginning of elaboration of influencing factors on the individual and societal perception of climate change via interactive learning modules (Basic Module 3).</li> </ul>	8b, 10a, 10b, 11a, 11b, 11c, 12c, 13a, 13b, 13c, 13d, 16e
<b>Homework</b>	<ul style="list-style-type: none"> <li>Self-directed elaboration of influencing factors on the individual and societal perception of climate change via interactive learning modules (Basic Module 3).</li> </ul>	7f, 9a, 10c, 11b, 11c, 13d
<b>B4</b>	<ul style="list-style-type: none"> <li>Consolidation of knowledge about influencing factors on the individual and societal perception of climate change in plenary session:               <ul style="list-style-type: none"> <li>Reflection of the concepts of “framing” and “agenda setting”,</li> <li>Online research on current examples for “framing” and “agenda setting” in regional media,</li> <li>Reflection of students’ real-life experiences with the influenceability of own perceptions.</li> </ul> </li> <li>Beginning of elaboration of specialisation modules on regional climate change (“Adaptation to climate change in cities”, “Climate change and forest ecosystems”, “Phenology as bioindicator for climate change”, “Climate-related changes of pollen-induced health stress”, “Selected approaches for climate protection in Bavaria”, “Climate change and the water cycle”, and “Climate change and soil ecosystems”).</li> <li>Students choose two out of a total of seven modules on specific thematic perspectives on climate change, based on their interests.</li> </ul>	2a, 6b, 8b, 10c, 11a, 11b, 11c, 12c, 13d, 16e
<b>Homework</b>	<ul style="list-style-type: none"> <li>Self-directed elaboration of specialisation modules on regional climate change.</li> <li>Preparation of a short presentation about one of the chosen specialisation modules in groups.</li> </ul>	2a, 7f, 9a, 10c, 13b

Table 3. Cont.

	Target-Group-Specific Operationalisation	Underlying Implementation Principles
B5 (2 weeks after B4)	<ul style="list-style-type: none"> <li>Short presentation of the elaborated content of the specialisation modules.</li> </ul>	12c
<b>Phase C</b> <b>Emergence and Planning</b> Eight sessions (90 min each) over the course of 10 weeks <b>10 weeks in total</b>		Applying to whole phase: 1c, 3a, 3b, 7c, 7d, 7e, 9b, 10a, 10b, 10c, 13a
C1	<ul style="list-style-type: none"> <li>Introduction and description of important chapters for the written seminar paper via a sample structure.</li> <li>Preview on the learning steps for the successful development of individual research plans (Advance Organizer).</li> <li>Formulation of students' initial research interests via the "flash response technique".</li> </ul>	2a, 15c, 15d, 16b, 16c, 16d, 16e
C2	<ul style="list-style-type: none"> <li>Introduction to and try-out of relevant research methods in a "gallery walk" (qualitative interview study, quantitative survey study, phenological observation, sensor-based soil moisture measurement, biological water analysis with indicator organisms, measurement of climate parameters with the "senseBox", bark beetle monitoring, dendrochronology, microscopic pollen analysis, and phenological lab experiments).</li> <li>Assignment of potentially suitable research methods to the respective individual fields of interest.</li> </ul>	2a, 2b, 2c, 4a, 6c, 8a, 15b, 16b, 16f
C3 (1 seminar session + 1 week for homework)	<ul style="list-style-type: none"> <li>Interest-based elaboration of content areas for the students' individual research projects via mind maps.</li> <li>Further elaboration via mutual peer-review of the mind maps.</li> <li>Introduction to means and techniques of scientific literature research.</li> <li>Narrowing down of the individual thematic contexts based on targeted literature research and structuring techniques.</li> </ul>	2a, 2b, 6b, 8b, 8c, 9a, 14a, 14b, 15a, 15b, 16b, 16f
C4 (1 seminar session + 1 week for homework)	<ul style="list-style-type: none"> <li>Common reflection of the aims and functions of a scientific research question.</li> <li>Provision of central quality criteria for adequate research questions.</li> <li>Further confinement and concretisation of individual thematic contexts based on targeted literature research and structuring techniques.</li> <li>First draft of individual research questions.</li> </ul>	2b, 8b, 9a, 13b, 14a, 14b, 15a, 15b, 16b, 16f
C5	<ul style="list-style-type: none"> <li>Typologizing of students' research question drafts (e.g., explain sth., design sth., determine a trend of sth. . . .).</li> <li>Mutual reflection of research question drafts via peer-feedback.</li> <li>Redaction of individual research questions.</li> <li>Criteria-based peer evaluation of research question drafts.</li> <li>Further redaction and submission of individual research questions to the teacher.</li> </ul>	2b, 2d, 8b, 8c, 13b, 14b, 15b, 16b, 16c, 16e, 16f

Table 3. Cont.

	Target-Group-Specific Operationalisation	Underlying Implementation Principles
C6	<ul style="list-style-type: none"> <li>Finalisation of students' research questions based on teacher feedback.</li> <li>Introduction of central characteristics and provision of quality criteria for an adequate methodical research design.</li> <li>First draft of individual methodical research designs based on students' individual research questions.</li> </ul>	2b, 2c, 2d, 4a, 13b, 14b, 15b, 16b, 16c, 16d, 16f
C7	<ul style="list-style-type: none"> <li>Mutual reflection of methodical research design drafts via peer-feedback.</li> <li>Redaction and finalisation of students' individual methodical research designs.</li> <li>Introduction of important considerations for chronological research plans.</li> <li>Beginning of development of individual chronological research plans.</li> </ul>	2c, 2d, 6c, 8b, 8c, 13b, 14b, 15b, 15d, 16b, 16d, 16e, 16f
C8	<ul style="list-style-type: none"> <li>Further development and finalisation of individual chronological research plans.</li> <li>Preview of field research phase.</li> <li>Introduction of a "researcher's logbook" as a documentation instrument for the field research phase.</li> </ul>	7c, 15d, 16c, 16d, 16f
<b>Phase D</b>		
<b>Field Research</b>		
	At least four sessions (90 min each) + students' individual research activities,  <b>12–16 weeks in total</b> (+ summer holidays)	Applying to whole phase: 1d, 3b, 4b, 4c, 5a, 7a, 7d, 7e, 9a, 10b, 11b, 11c, 14c, 14d
D1	<ul style="list-style-type: none"> <li>Reflection of previous work with the "researcher's logbook".</li> <li>Reflection of previous progress during the first weeks of students' field research with a special focus on potential difficulties.</li> <li>Common development of solution strategies for the most frequent problems.</li> <li>Individual elaboration of further research steps with support by the teacher.</li> </ul>	6a, 6c, 6d, 8a, 8b, 13c, 15b, 15c, 15d, 16b, 16d, 16e, 16f
D2	<ul style="list-style-type: none"> <li>Individual advisory and guidance of students during their individual field research by the teacher.</li> </ul>	5a, 6a, 6b, 6c, 6d, 7c, 11a, 13a, 15a, 15b, 15c, 15d, 16b, 16c, 16d
D3	<ul style="list-style-type: none"> <li>Mutual presentation of central aspects of the students' individual research projects in a "speed dating" scenario.</li> <li>Elaboration of flash presentations ("pitches") of the students' individual research projects.</li> <li>Application of the pitches in plenary as preliminary exercise for upcoming interim presentations.</li> </ul>	5b, 6d, 8c, 14e, 15b, 15c, 16f
D4/ ... (at least one pre-presentation session)	<ul style="list-style-type: none"> <li>Interim presentations of the students' individual research projects with focus on research question, data collection and first insights.</li> </ul>	5b, 6d, 14e, 15c

Table 3. Cont.

	Target-Group-Specific Operationalisation	Underlying Implementation Principles
	<b>Phase E</b> <b>Writing Workshop</b>	
	Six sessions (90 min each) until submission deadline for written seminar papers, + students' individual elaboration of their seminar papers	Applying to whole phase: 1e, 7b, 7d, 7e, 13a, 13b, 13c, 14e, 15b, 15d, 16b, 16d, 16e, 16f
	<b>6–8 weeks in total</b>	
E1	<ul style="list-style-type: none"> <li>• Wrap-up of the students' previous writing activities during the field research phase and summer holidays via the "flash response technique".</li> <li>• Workshop session on the requirements and quality criteria of the "Introduction" chapter of the written seminar paper:</li> <li>• Clarification of the central functions of the introduction chapter in a scientific paper.</li> <li>• Derivation of the requirements and quality criteria of the introduction chapter based on an example.</li> <li>• <b>Either</b> peer-review of already existing individual drafts, <b>or</b> elaboration of individual drafts for the introduction chapter within the seminar session.</li> </ul>	8c
E2–E6	<ul style="list-style-type: none"> <li>• Workshop sessions the chapters "Theoretical Background", "Research Question", "Methods", "Results", and "Discussion" of the written seminar paper: <ul style="list-style-type: none"> <li>○ Clarification of the central functions of the respective chapter in a scientific paper,</li> <li>○ Derivation of the requirements and quality criteria of the respective chapter based on an example,</li> <li>○ <b>Either</b> peer-review of already existing individual drafts, <b>or</b> elaboration of individual drafts for the respective chapter within the seminar session.</li> </ul> </li> </ul>	5b, 6a, 6b, 6c, 6d, 8c
	<b>Phase F</b> <b>Seminar Conclusion</b>	
	Timespan between submission of seminar papers and final presentations	Applying to whole phase: 1e, 7d, 7e, 9a
	<b>~2 months in total</b>	
F1/ ...	<ul style="list-style-type: none"> <li>• Preparation and realisation of the final presentations of the students' individual research projects. (usually carried out individually).</li> </ul>	5b, 6d, 14e

To demonstrate how these results were achieved, we exemplarily elucidate selected findings in the following. All the aforementioned research methods delivered important and useful data. Especially, the teachers' quotes obtained from the focus group discussions and the teacher surveys were most suitable to present vivid insights into the data. In the following, we therefore integrate exemplary quotes to illustrate our research findings.

On the whole, one overarching insight emerged from the data: in IBL, many factors—such as the composition and prerequisites of the learner group—come together to create learning processes that are often difficult to plan and that need to be guided and supported depending on the situation. This requires advanced competences from the teachers, such as for example procedural/methodical skills, factual knowledge, or the ability to provide ad hoc support in various learning situations. Consequently, many teachers expressed great uncertainty regarding their capability to adequately deal with all these eventualities, as, for

example (all quotes presented in this paper are translations of the original German-language source material):

*"[ . . . ] I have a [research question by a student] about climate-sceptical media and their influence on people. [...] For me this is rather difficult now, this whole media thing, as I am a natural scientist."*

*"The topic of research methods and their implementation is a challenge for many students which they do not really dare to approach, because such work is completely unknown to them, and they would like more preparation. Because of all the different [approaches], this is of course not easy [for me]."*

*"Beginning with session C2 [ . . . ], the teacher should also be clearly aware that all of the following work steps lead to the students' moving on to their research questions [ . . . ]. The challenge is that you calm down the students who panic quickly and assure them that they do not have to worry about choosing the wrong topic or about not finding a suitable research question."*

These insights clearly express the need to design the learning environment in a way that not only supports the students in their learning processes but also the teachers in guiding these learning processes. Therefore, this finding has not only led to the inductive development of respective design principles (see Table 2, principles 16a-16f), but has also strongly shaped the target-group-specific operationalisation of all the other design principles in the learning environment. In sum, we addressed these challenges in two ways: on the one hand, we optimized the teachers' manual by integrating numerous remarks, tips, suggestions, additional information and materials, and other supporting elements for the teachers (e.g., hints to provide learning impulses in particular lesson phases and brief heuristics on how these impulses could be given), and on the other hand, we modified the students' learning materials, tasks, and information sources so that they simultaneously aid the teachers to support students' learning processes.

This was the case, for instance, in phase B, which was designed particularly to enable students to acquire important knowledge about climate change on both a global and regional scale, which includes the differentiation of existing mental representations (conceptual change). To help teachers convey this complex, extensive knowledge (see implementation principle 16a), we developed a set of interactive online learning modules that focus on the causes and functionality of climate change, its global and regional effects, and the factors that influence the individual and societal perceptions of the phenomenon. To realise important design guidelines, such as 12 ("IBL should support students to intensively immerse into and research the factual basics of the respective context.") or 13 ("IBL should draw on targeted insights into authentic science."), these modules were designed to be very target oriented from the very beginning, for instance by including reflections on the nature of climate science and the validity of its findings. To present the modules' contents in a vivid, comprehensible way, they were designed in a multimedia format (text, tables, graphics, videos, audios, and interactive tasks). Additionally, they contain various self-examination and summary tasks to self-check the individual learning progress. Nevertheless, the evaluation of the pilot phase already showed that both motivation and learning success decreased over time when students only worked self-directedly via the online modules. As a consequence, following additional design principles like 8b ("IBL should include various occasions for common and mutual reflection."), we implemented fixed-point sessions in between the homework phases to discuss the content of the respective modules and to consolidate the desired knowledge in plenary. With this rearrangement, motivation and learning success during phase B could be significantly increased. Over the course of the main research cycles, the structure of these fixed-point sessions could be further improved: the final version of session B2, for example, was focused more strongly on supporting conceptual change (implementation principles 11a, 11b, and 11c) by implementing a classroom quiz and a role play in which students are asked to discuss causes and functionality of climate change from the perspectives of scientific common sense vs. climate

scepticism. The contents of the redesigned version of session B4 were oriented closer to students' everyday realities (e.g., implementation principles 6b and 10c), as they are required to reflect the influenceability of own perceptions, for instance by media "framing" and "agenda setting". The newly designed learning materials for these sessions at the same time represent an orientation for the teachers to support the consolidation of factual knowledge and to moderate reflection processes (implementation principles 16a and 16e). As focus-group discussions showed, the overall final structure of phase B met the desired goals:

*"So that's really great, the whole concept with the online course laboratory, all of the basic modules and specialisation modules that are stored there. The students loved it, really. So, they really enjoyed working with the whole thing. [...] I then wrote an impromptu task about it. [...] It turned out quite neatly too. [They] learned quite well."*

As a second main goal of phase B, which forms the basis for the emergence and planning phase, students should already be given the opportunity to focus on individual interests within the context of climate change (implementation principle 2a: "IBL should provide occasions that allow students to find individual fields of interest for their research projects"). For this purpose, we created different specialisation modules, which address regional implications of climate change from different thematic perspectives. They focus, for example, on interactions between climate change and forest ecosystems, effects of climate change on pollen allergies, or implications of climate change for urban areas.

In the pilot version of our seminar concept, every student was meant to work with every one of the specialisation modules and then choose their individual field of interest. As insights from the pilot phase indicated that students should be able to focus on individual interests earlier in the learning process, this part of phase B also underwent a redesign by applying additional design principles (such as 7f: "In IBL, students should be enabled to self-direct their acquisition of basic knowledge about the given thematic context to an adequate extent"). Students can now choose two out of seven of the specialisation modules to further engage with. That this indeed allows them to set a rough direction for their further planning is shown, for instance, by the following quote:

*"And what was very good in finding the research question were the specialisation modules. [...] I also had them give presentations there. After that, most of them already knew in which direction their research should go. Then they also developed their own ideas and then brought in a lot of personal things."*

The extensive field research period in phase D obviously enables the most self-directed and self-responsible activities of the students' individual research projects. While this comes along with extraordinary high degrees of autonomy, it also carries the risk for students to feel left alone or get bogged down in their research. Therefore, as our research has shown, an adequate amount of individual guidance is necessary in this phase, especially during the first weeks of field research. To pursue this goal, the idea of employing targeted fixed-point sessions, as described in the table (see Table 3, phase D), has proven to be suitable in general. At the same time, the individual counselling for students by the teacher turned out to be especially difficult and time-consuming:

*"Advising students is sometimes difficult, but necessary. [...] More time would be needed for the deliberations."*

Therefore, we redesigned session D2 via two major adjustments. On the one hand, we detached individual counselling from the idea of a single plenary session and instead recommended to spread the counselling sessions over several days. Additionally, teachers should request written progress descriptions by their students in advance. On the other hand, we formulated hints and key questions in the teachers' manual as a guideline for them to facilitate target-oriented advisory (which refers to design principles 16b, 16c, and 16d). Focus-group discussions showed that these adaptations led to significant improvements:

*“The one-on-one meetings that have already been held have worked very well. The students sent me information on the current status of their research by E-mail. This was extremely helpful for the individual advice.”*

In general, design guideline 5 (“IBL conceptions should provide an adequate amount of guidance for the students.”) has proven to play a major role. While each of the seminar phases is characterized by particular difficulties that require suitable guidance measures (e.g., the previously described self-directedness of phase D), one vivid example of this is the balance between teacher-guidance and peer-feedback, which plays an important role in several seminar sessions: Following design guideline 8 (“IBL conceptions should create various opportunities to experience research as a social, cooperative process.”), we implemented various occasions for students to mutually reflect on their progress and support each other by differentiated feedback (i.e., implementation principle 8b and 8c). Our data show that in many learning steps these peer activities were successful:

*“The peer review was very motivating, as the students asked their classmates questions and felt that they were being taken seriously. During this phase, the students were particularly focused. [...] Competence goal 1 [= ‘Students give their classmates constructive feedback on their Mind Maps.’] could be fully achieved in the peer review phase [...].”*

*“This phase [= phase C] worked very well, as the students quickly discovered critical points through the communicative exchange that they would hardly have come across on their own.”*

But on the other hand, we also found much evidence for situations in which such peer activities were not sufficient, but the respective tasks required stronger feedback and guidance by the teachers:

*“So there, [with] just this peer feedback, they were a bit unsure [...] whether [...] their research questions, their ideas, whether they can be implemented, whether this is something applicable. [...] At some point they said that it didn’t help them either, because they wanted to know what I was saying about it.”*

*“I mean, [ . . . ] you shouldn’t really be surprised if the whole school experience has so far resulted in the fact that the teacher clarifies what is right / important, how the course is to be set—of course it is clear that this expectation is there, too. In addition to the peer feedback, it is probably really important that the teacher gives this security.”*

Fortunately, there are also several components in the learning environment, for which the set of underlying design principles worked out quite well from the beginning and which therefore underwent no further adaptations. So, for example, research data on session A2 show almost entirely indications of successful learning processes. This session was designed to get students in touch with genuine research, as well as the climate change phenomenon, within their everyday realities. Here, the implementation principles 4b, 8a, 8b, 9a, 10a, 10b, 13a, 13b, 14c, 15b and 16b played especially major roles. These were operationalised with a brief excursion in the students’ home region, based on the “jigsaw” method. There, students are given the possibility to apply methods commonly used within a scientific discipline to exemplarily inquire into selected implications of climate change in their immediate surroundings and to share and reflect on their experiences in groups. Focus-group discussions showed that teachers perceived these activities as very successful (e.g., regarding the scientific connection between global climate processes and locally visible aspects) and observed intense and motivated learning processes among their students, as exemplarily illustrated in the following quotes:

*“Especially the entry into the seminar, where there was also a strong presence at school, was very successful, phase A. [A]nd then also with the [ . . . ] jigsaw-method, the students were very happy to do that.”*

*“[The] introduction to research methods was intensively conveyed especially via the excursion and was kept in remembrance by the students.”*

#### 4. Discussion

In this paper, we investigated how a science propaedeutic seminar on regional implications of climate change should be conceptualized in upper secondary schools to support successful learning processes in a close-to-science IBL approach. Therefore, we identified a set of influencing factors, which play an important role for the success of such approaches, particularly in the school context. Correspondingly to these factors, we derived and differentiated a catalogue of central design principles, as depicted in Chapter 3, on three different levels of operationalisation. Referring to RQ1a, especially the identified design guidelines and implementation principles represent insights on a theoretical level, which we consider as transferable to a certain extent. Applying them allows us to realise close-to-science IBL in upper secondary schools and similar educational contexts. As these principles provide a design framework, which was so far missing outside of the higher education context, they can form the basis for targeted science-propaedeutics at schools addressed to the acquisition of science literacy and other science-related competences (see [6,56]). Referring to RQ1b, we provide design principles on the most concrete level of target-group-specific operationalisation that simultaneously represent detailed context-specific how-to-guidelines for designing close-to-science IBL environments on the topic of climate change. As shown in chapter 1, such learning conceptions can support the achievement of climate literacy via the described characteristics and hitherto observed effects of IBL. Moreover, the final learning environment as a whole, which was created throughout the DBR-process, represents a valuable output on a practical level, as it is available for practitioners in an applicable, ready-to-use format.

Our findings stand in line with previous research on requirements and principles of good practice CCE: For instance, Cross and Congreve [116] identified seven principles for good climate change teaching in the context of undergraduate higher education which match our set of design principles in large parts. Their postulates, such as that in CCE assessment needs to be authentic, that students' skills to engage with climate change (as a wicked problem) should be clearly scaffolded, or that climate change teaching should be meaningfully enriched by appropriate technology can be confirmed by our design principles, respectively the experiences with our learning environment.

Nonetheless, the study is explicitly focused on close-to-science IBL. Against this background, the generated design principles and the resulting teaching concept can certainly only unfold their full effect in didactic arrangements that offer the framework conditions for close-to-science IBL. These temporal and organisational framework conditions are especially given in project-oriented teaching. The example of the science propaedeutic seminars in upper secondary schools in Bavaria shows what is possible at schools—if enough time is made available for inquiry-based learning. It is a great pleasure to experience the students' motivation and sense of achievement that can arise in such a learning arrangement. Unfortunately, however, such frameworks do not exist often, both in Germany and in an international perspective, and it is often not easy to create them given the complexity of educational systems. Often, individual schools can make few independent decisions because they are dependent on the educational policies of their district or state. We believe that IBL has such a high educational value that a course should be set in educational policy to provide such learning experiences to as many students as possible.

As one of the most central findings of this study, we consider the fact that the teachers in close-to-science IBL at schools represent an important influencing factor on the success of the learning processes, which is consistent with Hattie's findings [117,118] and in the context of climate change with implications made in a study by Onuoha et al. [119].

In line with this, our data shows comparatively high demand on teachers in IBL in many dimensions of professional teacher competence (see [120,121]). This is particularly true for the dimensions of Content Knowledge (CK) and Pedagogical Content Knowledge (PCK), because here these are not limited to the respective school subject (here geography). Rather, CK and PCK on a factual and procedural level extend to the whole scientific dimension of the subject, which goes well beyond what is usually required from teachers

in a school context. One potential attempt to address these challenges could consist in a more widespread integration of IBL into university-based teacher education, as for example Huber [26] or Fichten [79] demand. Inquiry-based learning in teacher education can not only be exciting and motivating, but also generate experiences from which students can later benefit. Teachers who have collected and analysed data themselves in their training and, in the best case, have also had the opportunity to reflect on the nature of science, can bring these competencies to bear in their work with their students.

Additionally, IBL requires advanced skills on the level of teacher noticing (see [122]), especially the many situations over the course of IBL processes, in which ad hoc support by the teacher becomes potentially necessary, that require both an advanced perception of students' need of guidance and an adequate reaction to it.

Beyond the dimension of professional skills and knowledge, we learned from teachers' feedback that they also felt uncomfortable with the different teacher role. In close-to-science IBL, teachers are not meant to be omniscient educators and conductors of the learning processes, but rather coaches and learning companions on eye-level with the students [64,85] and, as such, part of a research (and learning) collective. Against this background, a shift from still widely present transmissive views on learning to a more constructivist perspective seems necessary. Especially in the IBL context, approaches like Knowledge Building could be promising [123–125].

In sum, with its findings this study builds the foundation for further research. So, for example, a quantitative approach with standardised instruments seems very promising to assess the acquisition of intended science- and climate-related competences by students learning with the designed IBL environment. Additionally, effects of the conceptions on important CCE-related constructs could be measured in further studies, so for instance the reduction of psychological distance, the fostering of Conceptual Change, increases in critical thinking skills, or effects on students' interest and motivation.

### *Limitations*

Nevertheless, there are still some important aspects to shed light on. First, detailed insights particularly on the emergence and planning phase (= phase C in our conception) are missing so far. This is important in that a closer look, for example at official planning documents for school practice (e.g., [100]), shows that it is usually exactly this phase of the research cycle that is left out or at least vastly narrowed down. Given the fact, that this phase is explicitly considered as an important element of IBL [60,61,63], insights on the underlying difficulties and challenges are needed. Consequently, throughout our DBR project we have been collecting additional data on phase C, which is currently being analysed. Furthermore, our observations do show that our IBL environment can support dispositions for climate-related action among the students, but targeted educational elements to specifically foster climate-related action, respectively dispositions for action, are not yet implemented within the conception. Approaches to address this dimension are the subject of a current research project.

Additionally, research findings on the regional and individual approach, which is central to our IBL conception, are currently missing. The idea of students conducting research in their immediate surroundings, within their own everyday realities, and based on their individual interests represents a core element of our learning environment. Due to research literature, these characteristics are very likely to result in effects that are desirable in the CCE context (e.g., the reduction of psychological distance to the climate change phenomenon, or the fostering of conceptual change by own experiences). In our study, we have taken these theoretical linkages as basic presumptions on which we developed our conception. Nevertheless, it seems very promising to examine how far our IBL environment contributes to these effects. Here, targeted approaches might help to gain interesting insights. This also applies for the perspectives of the students. These were so far only assessed indirectly via the teachers' observations. Thus, it has not yet been finally clarified

how the learning environment affects motivation, interests, and willingness to engage in pro-environmental behaviour. Future research should therefore focus on these aspects.

So far, no research ethics have been addressed in the conceptualisation of the learning environment, as no challenges have arisen in connection with the research questions of the students. Therefore, it has not yet proven necessary to integrate the corresponding implementation principles. However, in cases where research questions with such challenges are chosen by the students, this might become important.

The applied method of participant observation might raise the question of to what extent the presence of the observer and his interaction with the students could have caused reactivity effects. Regarding the pilot cycle (and to a very limited extent possibly also regarding main cycle 1) these cannot be excluded, as during this phase interaction was necessary to find out which specific measures of guidance were needed by the students. For the main research cycles, especially cycle 2, such effects can be seen as very improbable because interaction between researchers and students was limited to small talk or organisational issues, as described above.

Further limitations relate to the applied DBR approach. So, for instance, it is obvious that the mere design of a learning environment cannot determine successful learning processes, considering the described significance of the teacher in close-to-science IBL. Possibilities in DBR to address this factor are predominantly limited to the learning environment, while, for example, teacher education can hardly be influenced. Nevertheless, through the DBR process we were able to identify design principles to support teachers in guiding students' learning processes the best way possible, which we operationalised in the resulting learning environment and implemented into complementary measures like the aforementioned teacher training (see Section 2.1).

Besides that, the DBR approach, aiming to create a complex set of design principles as a theoretical and practical output, is not capable of identifying isolated variables. Causal statements in the format of "x leads to y" are not possible because the applied design principles always work together as a whole to achieve a particular effect. This is naturally inevitable in DBR, but at the same time this approach allows us to comprehensively capture as many potentially relevant context factors as possible and to create a learning environment that, as a whole, achieves desirable effects. This represents a great advantage in exploratory research projects.

DBR with its iterative character also brings the question about when to consider a conception and the respective design principles as "final". In theory, the more iterations one executes, the more differentiated the output becomes. In our project, we decided to complete the research process after one pilot cycle and two main research cycles for two main reasons. First, our conception meets four central criteria that usually determine the number of iterations in practice [126,127]. It is designed on the basis of state-of-the-art knowledge (content validity), its constituting parts are linked to each other in a logical, coherent way (construct validity), the end users can apply it in the way it was intended by the developers (practicality), and it results in the desired learning outcomes (effectiveness). Second, a perpetual in-detail adaptation would not be practicable, in that beyond a certain threshold it would only result in reactions to the individual characteristics and needs of the respective learner group in which it was applied—in other words, even if the learning environment is developed to an optimal state in general, there will always be a margin for improvement when addressing a particular learner group.

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#### 4.3 Beitrag 3: Finding a research question and developing a research plan in Inquiry-Based Learning: Particular challenges and guidance approaches

Der nachfolgende Beitrag ist 2026 im Fachjournal „International Journal of Science Education“ erschienen. Für die bibliographischen Angaben siehe Brumann & Ohl (2026) im Literaturverzeichnis.

Bei der hier abgedruckten Version handelt es sich um das final beim Verlag zur Veröffentlichung akzeptierte Manuskript. Dieses wurde inhaltlich unverändert veröffentlicht, jedoch in Format bzw. Layout vor dem Druck durch den Verlag noch angepasst.

**File not for review**

**Finding a Research Question and Developing a Research Plan in Upper  
Secondary School Inquiry-Based Learning: Challenges and Guidance  
Approaches**

International Journal of Science Education

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## **Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## **Biographical notes**

Sebastian Brumann is scientific director of the Deutsches Museum's teacher training facility "Kerschensteiner Kolleg". He studied Geography and German studies at the University of Augsburg and graduated in 2016 with the Erstes Staatsexamen. Between 2016 and 2023, he was a research associate at the Chair of Geography Education at the University of Augsburg. In his PhD thesis, Sebastian Brumann developed and evaluated a climate change education concept for upper secondary schools based on the Inquiry-Based Learning Approach.

Ulrike Ohl is Professor and Head of the Chair of Geography Education at the University of Augsburg, Germany. In her research, she focuses on professionalising future geography teachers, education for sustainable development, transformative learning, and climate change education. Research projects under her supervision aim to connect theoretical and practical perspectives; intervention research and design-based research are central approaches in this regard.

### **Ethics Statement**

The study was situated within a regular school setting and adhered to standard educational research practices. Data collection was limited to anonymised teacher feedback and observations related to teaching strategies, without involving sensitive data, thus ethics approval was not required.

### **Disclosure of AI Use**

In the preparation of this manuscript, Chat GPT 4o was used to shorten text passages and DeepL Translate to assist with translations.

**Word Count:** 8520 words

# Finding a Research Question and Developing a Research Plan in Upper Secondary School Inquiry-Based Learning: Challenges and Guidance Approaches

**Background:** The development of research questions, elaboration of methodical research designs and planning of inquiry projects by school students are considered as key elements of close-to-science inquiry-based learning (IBL). Yet, detailed insights on these activities are still largely missing.

**Methods:** Using Design-Based Research, an IBL environment for science-propaedeutic seminars on regional climate change in Bavarian upper secondary schools was developed and applied in 75 seminars. The students' learning processes were assessed in 19 seminars through a triangulation of participant observation, semi-standardised teacher feedback and focus group discussions among teachers. Based on qualitative content analysis, central learning challenges and instructional strategies to address them were identified.

**Findings:** Results show that support measures must be tailored to target students' knowledge about research (processes), understanding of required learning steps, heuristics for IBL procedures, cooperative skills, individual interests, self-direction skills, or motivation. Guidance approaches identified as effective in this regard are for example: advance organisers to clarify learning steps, vivid examples of expected learning products, supportive materials for teachers, or the provision of clear guidelines, criteria, scaffolds, and heuristics.

**Contribution:** In an authentic learning environment, the study identifies factors that can impede learning processes in IBL, as well as instructional strategies to address them.

Keywords: inquiry-based learning; learning challenges in IBL; guidance measures for IBL

## **Introduction**

### ***Inquiry-based learning as a promising learning approach***

Instructional practices engaging students in scientific reasoning and research date back to the 1960s but gained increased attention over the past three decades due to their inclusion in educational standards worldwide (Apedoe et al., 2006; Chinn & Malhotra, 2002; Costes-Onishi et al., 2020; Crawford, 2014; Furtak et al., 2012; Lazonder & Harmsen, 2016; Levy et al., 2013; National Research Council, 2012). Despite varied terminology (Furtak et al., 2012; Lazonder & Harmsen, 2016; Scott & Friesen, 2013), these approaches are commonly grouped under the term Inquiry-Based Learning (IBL) (Spronken-Smith & Kingham, 2009). IBL aims to empower students to pose questions, conduct investigations, and justify findings using scientific methods, procedures, and attitudes (Lazonder & Harmsen, 2016; Messner, 2009; Pedaste et al., 2015).

IBL is considered a cornerstone of science education, enhancing scientific literacy (Gormally et al., 2009), scientific process skills (Mutlu, 2020; Nunaki et al., 2020), conceptual understanding (Chang & Mao, 1999; Costes-Onishi et al., 2020; Klein, 1995), academic achievement (Buchanan et al., 2016; Reitingner & Altrichter, 2022), scientific reasoning and problem-solving (Buchanan et al., 2016), critical thinking (Al-Maktoumi et al., 2016; Duran & Dökme, 2016), and collaboration and communication skills (Barron & Darling-Hammond, 2010; Chen, 2021). Consequently, it is seen as key to fostering 21st-century competencies (Barron & Darling-Hammond, 2010; Chu, 2017).

### ***Different formats of IBL***

IBL's effectiveness depends on the design of the learning environment, which varies across contexts (Levy et al., 2013). School-based IBL ranges from strongly didactically reduced approaches to open-ended, authentic research experiences. Models (e.g., Banchi & Bell, 2008; Bevins & Price, 2016; Schneider & Wildt, 2007; Willison & O'Regan, 2007) depict IBL as a

developmental trajectory: Early stages involve teacher-provided questions, data, and interpretations as well as pre-determined learning steps (cf. Banchi & Bell, 2008; Schneider & Wildt, 2007; Willison & O'Regan, 2007), while advanced stages allow student-generated questions, self-directed data collection and analysis via student-developed methodical approaches, and autonomous interpretation of findings (cf. Banchi & Bell, 2008; Schneider & Wildt, 2007; Willison & O'Regan, 2007).

### ***The role of question development and research planning in IBL***

Especially open, close-to-science IBL formats typically follow phases of an idealised research cycle (Huber, 2014; Pedaste, 2022; Pedaste et al., 2015). Within these phases, developing a research question, a methodical design and a research plan are central elements (Bornemann, 2021; Huber, 2014; National Research Council, 2012; Pedaste, 2022; Pedaste et al., 2015; Wildt, 2009).

Good research questions are among the most critical aspects of research (Alvesson & Sandberg, 2013). They make 'the rest of the inquiry cycle productive' (Kuhn & Pease, 2008), by specifying a project's epistemological interest and relevant constructs (Aeppli et al., 2016; Alvesson & Sandberg, 2013; Bortz & Döring, 2005), and by guiding research design and method selection (Alvesson & Sandberg, 2013; Bortz & Döring, 2005; National Research Council, 2012). Once a feasible question is identified, subsequent research processes become easier for students (Guo et al., 2018), while many problems experienced by learners in IBL go back to poorly formulated research questions (Brinkman & van Rens, 1999). Hence, formulating questions is a core skill for becoming an effective researcher (Walkington et al., 2011). Questions formulated by the students themselves are particularly valuable in IBL (Chin & Osborne, 2008; Herranen & Aksela, 2019; Huber, 2004; Zion & Mendelovici, 2012). Student ownership of research questions (Herranen & Aksela, 2019; Lombard & Schneider, 2013), i.e., pursuing personally meaningful questions tied to real-life contexts, is regarded as

pivotal for sustained engagement throughout laborious and often non-linear research processes, including detours and setbacks (Aeppli et al., 2016; Bornemann, 2021). Further, integrating students' individual questions can improve their conceptual knowledge and scientific understanding (Bielik & Yarden, 2016; Levy et al., 2013; Lombard & Schneider, 2013).

A well-aligned methodological design determines whether research questions can be meaningfully answered (Moser, 2015), including choices about measurements, required precision, and suitable instruments (National Research Council, 2012). Such considerations involve metacognitive processes like the critical review and evaluation of these components (Crawford, 2014). Involving students in inquiry activities, particularly through designing empirical investigations, appears as an expedient way to engage them in metacognitive thinking (Etkina et al., 2010).

Students must also organise and manage their inquiry process, including time and resources (Aeppli et al., 2016; Edelson et al., 1999). This entails setting goals, timelines, and coordinating research activities (Aeppli et al., 2016; Edelson et al., 1999).

### ***Challenges in the initial phases of IBL***

The initial phases of a research process – especially question formulation and research planning – are considered the most challenging (Bell et al., 2010; Beyerlin et al., 2020; Guo et al., 2018; Hartung, 2018; Popov & Tevel, 2007; van der Schee, 2001), as students need recurring practice to master the corresponding skills (Kuhn & Pease, 2008; Lombard & Schneider, 2013). Partially, these challenges can be traced back to the following factors:

#### ***Knowledge***

Research-related knowledge is a key factor in IBL, impacting all inquiry phases where students must acquire content, procedural, and epistemic knowledge (Edelson et al., 1999; Khalaf & Zin, 2018; White & Frederiksen, 2005). Students often lack this foundation

(Heidinger, 2016; Sievers & Westphal, 2018). Due to limited experience, when generating questions, students struggle to refine vague interests into specific, researchable problems (Popov & Tevel, 2007) and often tend to formulate overly broad or unfeasible questions (Barron & Darling-Hammond, 2010; Neber, 2004; Larotta, 2007). Moreover, designing a research project requires basic knowledge of investigative methods and their proper use (Aeppli et al., 2016; Edelson et al., 1999), which learners typically do not yet possess (Sievers & Westphal, 2018).

### *Motivation*

IBL demands a shift from receptive understanding to knowledge production through investigation (Bornemann, 2021; Decker & Mucha, 2018). Thoroughly exploring problems requires sustained effort to overcome internal barriers and anticipate outcomes (Decker & Mucha, 2018). This workload makes motivation challenging (Gormally et al., 2009). Setbacks, such as repeated attempts at question formulation, can lead to frustration (Beyerlin et al., 2020; Bell et al., 2010).

### *Self-organisation*

Self-directed knowledge production in IBL entails high demands on self-organisation, regulation, and responsibility (Beyerlin et al., 2020; Zhang & Quintana, 2012). Learners find it difficult to monitor goals, apply suitable strategies (Zhang & Quintana, 2012), and reflect on the progress of learning steps (Edelson et al., 1999). They often struggle to assess processes such as literature research, formulating research questions, or designing appropriate methods (Sievers & Westphal, 2018).

### *Time*

Limited time is a frequently cited barrier to successful IBL (Aeppli et al., 2016; Beyerlin et al., 2020; Chinn & Malhotra, 2002; Gormally et al., 2009; Heidinger, 2016; Khalaf & Zin,

2018). Students need time to understand the topic, then gradually develop and refine an empirically researchable question (Aeppli et al., 2016; Decker & Mucha, 2018).

### ***Adequate guidance measures for finding research questions and planning research activities in IBL***

Studies suggest that authentic, appropriately complex materials (Lombard & Schneider, 2013), iterative training in question formulation (Lombard & Schneider, 2013; van der Schee, 2001), mutual reflection and collaboration (Bruce & Casey, 2012; Lombard & Schneider, 2013), and a balanced mix of teacher support and student autonomy (Lombard & Schneider, 2013) foster the development of research questions. However, a review by Rönnebeck et al. (2016) highlights a lack of concrete instructional strategies targeting this ability. Regarding methodological design, most studies emphasise intensive scaffolding and teacher guidance, often involving predefined guidelines or selected materials (Rönnebeck et al., 2016).

### **Purpose, context and research questions of the study**

#### ***Purpose of the study***

Research on the IBL phase in which students develop research questions, methodological designs, and research plans (here termed ‘question development and research planning phase’) remains limited. While some general challenging factors have been identified, systematic insights remain scarce. Similarly, there is a lack of empirically grounded knowledge on effective instructional approaches to support this phase – particularly in close-to-science IBL. More detailed understanding is needed regarding both the challenges students face during this phase and concrete instructional strategies to address them. This study addresses these aspects by examining a learning environment designed in a previous research project.

### *Context of the study*

In preparation for academic work, upper-level high school students in Bavaria (aged 16 to 18) participate in a year-and-a-half science propaedeutic seminar ('W-Seminar'). This seminar begins with content and methodological instruction and guides students toward developing challenging, inquiry-based questions within a subject-specific framework theme. These questions form the basis for a full research cycle, culminating in writing individual seminar papers (Bayerisches Staatsministerium für Unterricht und Kultus, 2023).

The University of Augsburg developed an innovative concept for such a seminar to create a learning environment that mirrors authentic research and connects to students' everyday realities. It focuses on exploring regional effects of climate change from a geographical perspective. To date, the concept was applied in 75 seminars, including numerous high-quality and prize-winning student projects. The learning environment and its underlying principles were published in Brumann et al. (2022). A core feature of the concept is a dedicated phase for students to systematically develop research questions, methodological designs, and chronological plans. Data collected during application and assessment of this phase serve as the basis for this study's guiding research questions:

### *Research questions*

**RQ1:** Which particular challenges during the students' interest-based development of individual research questions and their methodical and organisational planning of research activities can be identified?

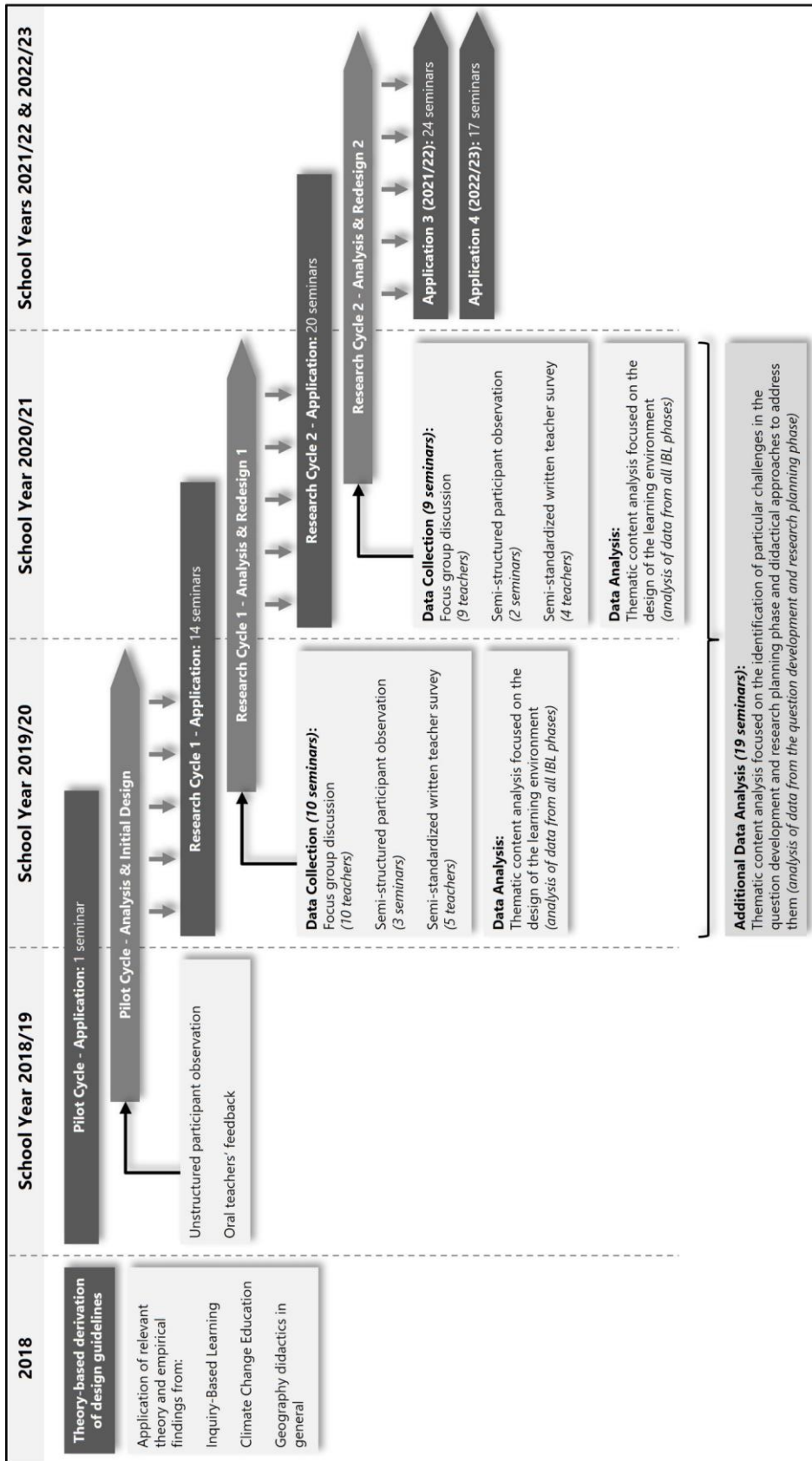
**RQ2:** Which didactic approaches are suitable for addressing the identified challenges?

### **Methods**

#### *Design of the learning environment*

To design the superordinate IBL environment, a Design-Based Research (DBR) approach was adopted, enabling both practical and theoretical insights (Bakker, 2018; Feulner et al., 2021;

Kelly, 2013). The iterative process involved close collaboration with practitioners (here: high school teachers) and aimed to develop a practically functional IBL environment while advancing and refining theory. As shown in Figure 1, the IBL environment was developed during a pilot and two main research cycles, drawing on theory and prior empirical findings. This included existing insights on the IBL phase of question development and investigation planning, as outlined in the 'Introduction' section. The concept was implemented in science propaedeutic seminars at Bavarian high schools and evaluated empirically (see 'Data Collection' and 'Data Analysis'). Based on the results, the design was revised and tested in the respective following research cycle.



**Figure 1.** Schematic structure of the DBR process to develop the IBL environment (own representation)

To ensure proper implementation, each research cycle began with a three-day teacher training in advance of the seminar start, which was open to all teachers interested in participating. The teacher training was aligned with the content and chronology of the IBL environment as published in the teacher manual (Brumann et al., 2022). Using this manual as a reference, the content, methods and associated competences were interactively developed and reflected upon with the teachers over a period of three days. In all schools, the same teacher guided the same student group throughout. Data for this study were collected during main research cycles one and two, covering 19 seminars. As part of the overall one-and-a-half-year learning environment, the design of the research question and planning phase evolved during the DBR process, grounded in existing knowledge regarding the didactic challenges and appropriate support measures in this IBL phase. The resulting conception for this phase of the learning environment comprises 14 key learning steps across eight seminar sessions over ten weeks. Each seminar session lasted 90 minutes, and each seminar was attended by 12-15 students. Table 1 shows the final structure of these steps (left column), their session allocation (middle column), and the didactical elements that supported learning (right column).

The research questions formulated above were explored based on this learning environment in its respective cycle-specific versions.

**Table 1.** Final structure of the learning steps for the question development and research planning phase in the IBL environment.

Learning Steps	Session Nr.	Implemented Didactical Elements
<p><b>Learning step 1</b></p> <p>Preview and discussion of the subsequent learning steps</p>	Session 1	<p>Grey = former elements that were removed later            Black = integrated starting with research cycle 1  <u>Underlined = integrated starting with research cycle 2</u>  <i>Italics = integrated after research cycle 2 for final version</i>            [square brackets] = remarks on relocated or removed elements</p> <ul style="list-style-type: none"> <li>• Initial ‘time travel’ scenario to discuss necessary planning steps to succeed in individual research projects.</li> <li>• <u>Preview and discussion of a sample outline for a seminar paper to derive the planning steps required for writing such a seminar paper later.</u></li> <li>• <u>Preview of the upcoming learning steps via an information sheet (advance organiser).</u></li> <li>• <i>Preparatory discussion of the upcoming learning steps.</i></li> <li>• Discussion of elements of a good research plan using a worksheet. [integrated starting with research cycle 2; removed after research cycle 2]</li> </ul>
<p><b>Learning step 2</b></p> <p>Identification of individual research interests</p>	Session 1	<ul style="list-style-type: none"> <li>• <u>Based on the elaboration of the seminar topics’ factual basics in the preceding seminar phase: Identification and discussion of first individual research interests via the ‘think-pair-share’-method.</u> [in research cycle 2: located in session 2]</li> </ul>

<p><b>Learning step 3</b></p> <p>Introduction to potential research methods with reference to individual interests</p>	<p>Session 2</p>	<ul style="list-style-type: none"> <li>• Introduction to scientific literature research through a university library visit. [removed after research cycle 1]</li> <li>• <u>Explication of upcoming learning steps (advance organiser).</u></li> <li>• Exploration of potentially relevant research methods in a ‘gallery walk’ (qualitative interview study, quantitative survey study, phenological observation, sensor-based soil moisture measurement, water analysis with indicator organisms, sensor-based measurement of climate parameters, bark beetle monitoring, dendrochronology, microscopic pollen analysis, phenological lab experiments). [in research cycle 1: located in session 1]</li> <li>• <u>Matching of the students’ individual fields of interest with potentially suitable research methods using a worksheet + classroom discussion.</u></li> </ul>
<p><b>Learning step 4</b></p> <p>Elaboration and structuring of thematic interests via mind maps</p>	<p>Session 3 + Homework</p>	<ul style="list-style-type: none"> <li>• <u>Explication of upcoming learning steps (advance organiser).</u></li> <li>• Interest-based elaboration of content areas for the students’ individual research projects via mind maps. [<i>in research cycle 1: realised as preparatory homework for session 3</i>]</li> <li>• Further elaboration of the students’ individual thematic interests via mutual peer-review of the mind maps.</li> </ul>
<p><b>Learning step 5</b></p> <p>Narrowing down of individual topics based on literature research</p>	<p>Session 3 + Homework</p>	<ul style="list-style-type: none"> <li>• <i>Introduction to means and techniques of scientific literature research using a sample video and an information sheet.</i></li> <li>• Narrowing of the individual thematic contexts based on targeted literature research and structuring techniques. → <u>Individual homework phase (1 additional week)</u></li> </ul>
<p><b>Learning step 6</b></p> <p>Reflection on aims and functions of a scientific research question and elaboration of central</p>	<p>Session 4 + Homework</p>	<ul style="list-style-type: none"> <li>• Preparatory classroom discussion on aims and functions of a scientific research question <u>using an information sheet.</u></li> <li>• <u>Explication of upcoming learning steps (advance Organiser).</u></li> <li>• Elaboration and discussion of central quality criteria for research questions using a worksheet.</li> <li>• <i>Preparatory discussion of a worksheet for the further confinement of topics and derivation of research question drafts.</i></li> </ul>

<p>quality criteria for research questions</p>		
<p><b>Learning step 7</b> Further confinement of topics and formulation of first research question drafts</p>		<ul style="list-style-type: none"> <li>• Further confinement and concretisation of the students' individual research topics based on a worksheet [extended to homework phase after RC2] <i>and targeted literature research</i>.</li> <li>• Derivation of a first draft of individual research questions [extended to homework phase after RC2] <u>with the help of vivid examples for orientation</u>. → <i>Individual homework phase (1 additional week)</i></li> </ul>
<p><b>Learning step 8</b> Reflection, peer-feedback and peer-review on research question drafts and successive redaction of research questions</p>	<p>Session 5</p>	<ul style="list-style-type: none"> <li>• <u>Explication of upcoming learning steps (advance organiser)</u>.</li> <li>• Typologizing of students' research question drafts (e.g., explain sth., design sth., determine a trend of sth. ...).</li> <li>• Mutual reflection of the students' research question drafts via peer-feedback and subsequent redaction of the research question drafts.</li> <li>• Mutual peer-review of the students' research question drafts using a criteria-based evaluation form + further redaction.</li> <li>• Reflection on fears and hopes regarding the successful applicability of the students' research questions. [removed after research cycle 1]</li> <li>• Submission of the research question drafts to the teacher.</li> </ul>
<p><b>Learning step 9</b> Finalisation of research question drafts based on teacher-feedback</p>	<p>Session 6</p>	<ul style="list-style-type: none"> <li>• Finalisation of students' research questions based on teacher feedback.</li> </ul>
<p><b>Learning step 10</b> Introduction to characteristics and quality</p>		<ul style="list-style-type: none"> <li>• <u>Explication of upcoming learning steps (advance organiser)</u>.</li> <li>• Introduction and discussion of central characteristics of and quality criteria for an adequate methodical research design using an information sheet and vivid examples.</li> </ul>

<p>criteria for a methodical research design</p>		
<p><b>Learning step 11</b> First draft of individual methodical research designs</p>		<ul style="list-style-type: none"> <li>• Elaboration of first drafts of individual methodical research designs based on students' individual research questions using a sample template and with the help of vivid examples for orientation.</li> </ul>
<p><b>Learning step 12</b> Finalisation of methodical designs based on reflection and peer-feedback</p>	<i>Session 7</i>	<ul style="list-style-type: none"> <li>• <u>Explication of upcoming learning steps (advance organiser).</u></li> <li>• <u>Mutual reflection of the students' methodical research design drafts via peer-feedback.</u></li> <li>• Redaction and finalisation of students' methodical research designs. [in research cycle 1+2: located in session 6]</li> </ul>
<p><b>Learning step 13</b> Beginning of development of chronological research plans</p>	<i>Session 7</i>	<ul style="list-style-type: none"> <li>• Introduction and discussion of important aspects for a chronological research plan using vivid examples.</li> <li>• Beginning of the students' development of individual chronological research plans using a sample template and with the help of vivid examples for orientation.</li> </ul>
<p><b>Learning step 14</b> Finalisation of research plans and preview on field research phase</p>	<i>Session 8</i>	<ul style="list-style-type: none"> <li>• <u>Explication of upcoming learning steps (advance organiser).</u></li> <li>• Finalisation of students' chronological research plans with individual support by the teacher. [in research cycle 1+2: located in session 7]</li> <li>• Preview of field research phase and introduction of a 'researcher's logbook' as documentation instrument for the field research phase. [in research cycle 1+2: located in session 7]</li> </ul>

### *Data collection*

This study aimed to identify key challenges in the question development and research planning phase and to describe effective strategies to address them. Therefore, an exploratory research strategy was adopted, characterized by an open, theory-building orientation that seeks to gain in-depth understanding of a phenomenon in its natural context rather than to test predefined hypotheses (Döring & Bortz, 2016; Flick, 2019). In line with this, we examined learning processes in an authentic school setting rather than under tightly controlled experimental conditions, applying a triangulation of qualitative methods to capture complementary perspectives from teachers, students, and researchers.

Subject of the research were the students' learning processes and how these were influenced by didactic measures. Teachers were not assessed on their performance or IBL-related skills, but were included in the study in their role as factors influencing the learning processes of the students. The sample consisted of those learning groups whose teachers had voluntarily opened up the seminars at their school for scientific monitoring and had attended the three-day teacher training course prior to the start of the seminar.

### *Semi-standardised written teacher survey*

To gain detailed feedback from teachers who implemented the seminar concept during the two main research cycles, we used semi-standardised questionnaires (Döring & Bortz, 2016; Jansen, 2010). Five teachers in cycle one and four in cycle two responded to each seminar session, with different teachers participating in each cycle. The questions were formulated in an open manner to identify as many factors relevant to the learning process as possible, including such factors that were not known in advance. This enabled the comprehensive documentation of detailed observations and experiences of the teachers – the analysis of which, in turn, formed an important basis for the further development and modification of the design principles. The questions were:

- How would you rate the overall concept for this lesson? What was good, what could be improved?
- At which points were the competence goals for this lesson achieved, which competence goals could not be achieved?
- How appropriate do you think the consideration of the students' individual interests was in this lesson? What suggestions for improvement can you think of?
- At which points in this session did you find the approaches or measures to support the students (e.g. through working materials, specific teaching steps, etc.) appropriate, and where not? What suggestions for improvement can you think of?
- At which points did you, as a teacher, get on well with the concept of this session, and where less so? What was the reason for this in each case? What suggestions for improvement can you think of?
- How would you rate the level and form(s) of social interaction (e.g. through group work, peer feedback, etc.) in this session and how successful it was? What suggestions for improvement can you think of?
- How would you rate your students' motivation in this session and what do you think influenced it?
- In your opinion, how clear was the necessity of the individual working steps and the objectives of this session to the students?
- How appropriate do you consider the orientation of this session towards 'real' science to be?
- What other observations or suggestions for improvement do you have in mind regarding this meeting?

### *Participant observation*

Teachers' perspectives were complemented by semi-structured participant observations (Döring & Bortz, 2016; Flick, 2019). In selected seminars, a researcher was present throughout the seminar application (three in cycle one, two in cycle two), using a semi-structured observation sheet to document, for example, task outcomes, comprehension difficulties, motivation, or teacher-student interaction. Interaction with students was minimal and limited to brief organisational exchanges. Observation data were digitised for analysis.

### *Focus group discussions*

We also conducted focus group discussions with teachers who implemented the IBL environment (Döring & Bortz, 2016; Flick, 2019; Moser, 2015). Ten teachers participated in the discussions in research cycle one and nine in cycle two, with different teachers participating in each cycle. Discussions focused on the structure, success, and clarity of the learning steps, the effectiveness of guidance measures, student motivation, and suggestions for improvement. Sessions were videotaped and transcribed for analysis.

### *Data analysis*

Observation sheets, teacher feedback, and focus group data were analysed using thematic qualitative content analysis (Kuckartz, 2018). This approach was chosen because it combines deductive, theory-informed categories with inductively developed, data-driven ones, allowing relevant themes to emerge from the material while remaining anchored in established conceptual dimensions. Hence, it reflects the exploratory character of the research strategy. The goal was twofold: to identify effective learning processes and retain successful elements, and to detect student difficulties in order to revise the learning environment accordingly. Categories for these analyses were generated deductively from literature and prior research cycles, as well as inductively from the data. The deductive categories were grounded in established dimensions of inquiry-based learning (e.g., scaffolding requirements, conceptual

understanding, learning motivation, or peer interaction), as these have been shown to shape typical points of difficulty during early research phases. These deductive starting points were then refined and complemented through inductive coding, allowing additional context-specific challenges to emerge from the classroom data. Analyses were conducted separately for each of the two research cycles (see Figure 1), providing a pre-structured basis of challenges and effective didactic elements for the current study.

Building on this, a second thematic analysis was conducted to organise the identified challenges. Coded segments reflecting learning difficulties were grouped into broader challenge categories – both derived from literature and developed inductively from the material.

The analyses draw on all data from both research cycles. As the learning environment evolved between cycles (see Table 1), comparing them allowed for a more comprehensive understanding of challenges.

To identify effective teaching strategies, revision measures from each cycle were summarised. Measures taken after cycle one were evaluated using data from cycle two, by identifying segments indicating improved learning outcomes. Since no further cycle followed the redesign after cycle two, the effectiveness of those later measures could not be empirically assessed. However, informal teacher feedback from subsequent implementations provided partial insight into their potential suitability.

### ***Quality assurance measures***

To ensure methodological quality, established qualitative research standards were followed (Göhner & Krell, 2020): The Design-Based Research approach and all data collection and analysis methods were applied systematically in accordance with standard scientific procedures. A triangulation of the three qualitative methods ensured data richness.

The category system was reviewed in expert research colloquia. To ensure reliability, a second rater was trained and independently coded 25% of the material. Inter-rater reliability was established through a consensus-based validation of the coding scheme: divergences were discussed until full agreement was reached, which led to the refinement of category descriptions (e.g., clarification of boundaries between subcategories and addition of anchor examples).

## **Results**

To answer the research questions, the identified challenges will be described as a first step. In a second step, the didactical approaches to address these challenges will be outlined.

Illustrative quotes from the data were translated into English by the authors.

### ***Identified core problems and context factors***

The analysis revealed several core problems occurring during the development of research questions, methodical designs, and research plans. Additionally, context factors – such as school conditions, teacher characteristics, and group dynamics – were found to influence all learning steps and interact with the core problems. Table 2 summarises both types of challenges with examples from the data.

**Table 2.** Identified challenges during the question development and research planning phase in IBL. Each example includes brackets specifying the data type (TF = Teacher Feedback, PO = Participant Observation, FGD = Focus Group Discussion) and the seminar session (cf. Table 1) from which it originates (except for focus group discussions).

<b>Identified challenges</b>	<b>Description</b>	<b>Examples from the analyzed data</b>
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## Core problems

Missing knowledge about / experience with research	Situations in which the students' missing prior knowledge about / experience with research processes, respectively IBL, posed a problem for the students' learning processes.	(a) 'When teaching, it felt like poking around in the dark. The impulse question [in the teacher's manual] assumes that the students know that [narrowing down a topic] is not enough. But my students don't realise that at all. They also don't know how to formulate research questions. With this question [of why a research question is necessary], they should at least have an idea already of what a research question is and why you need to ask it precisely. But they don't know that.' (TF, S.4)
Insufficient understanding of the succession, functions and/or goals of learning steps	Situations in which students' insufficient understanding of the succession, functions and/or goals of certain learning steps during the development of individual research questions, methodical research designs and chronological research plans represented a problem.	(b) 'Some of my students did not realise that they were already dealing with their research question or they were not fully aware of the path from the large mind map through increasingly focused narrowing down to the concrete research question.' (TF, S.4) (c) 'I think the students did not realise how broadly this topic should be defined, i.e., more in the sense of: 'perception of different facets of climate change' or 'perception of climate change by 8th grade high school students compared to the perception of 8th grade middle school students'.' (TF, S.1)
Missing / deficient heuristics for learning steps	Situations in which students' missing or deficient heuristics to carry out a learning step were identified as a problem.	(d) '[With regard to] literature research, [you should] actually show the students how it works [...]. Perhaps using an example that they can practice with. Or, well, in any case, that you are taken along on such literature research.' (Focus group discussion [FGD] 2) (e) '[Most] students do not seem to understand why and, above all, how they should improve their research question [...]. In order to encourage [them] to optimise their research questions, it seems important to me to [help them] understand the 'why?' on the one hand and to point out fruitful

		approaches/options on the other.’ (PO, S.6)
Uncertainties in the planning of research processes	Situations in which the students had problems dealing with uncertainties that are inherent to (planning) research processes.	(f) ‘It would also certainly help the students if they knew that both the [methodical] plan and the timetable can be adapted again and again in the course of their own research activities, so it is not set in stone.’ (TF, S.6)
Problems with cooperative activities	Situations in which students’ insufficient motivation or ability to carry out cooperative learning activities, such as giving mutual feedback or reviewing each other’s interim products, were identified as a problem.	(g) ‘The peer reviews ease the working atmosphere and are useful in many places, but it turns out that a lot of feedback is still quite superficial, which is typical for school, especially when assessment criteria are a bit ‘more free’ or because some (also otherwise rather weak) participants have not understood steps sufficiently or lack an eye for quality due to a lack of experience.’ (TF, S.7)
Difficulties to become aware of and pursue own interests	Situations in which students’ difficulties to explicate their own interests or to carry out a learning step based on their own ideas or interests (as opposed to teacher-provided ideas) could be observed.	(h) ‘Some students actually followed their personal interests and were therefore able to formulate an interesting [topic]. For other students, the whole thing was probably still too vague and they were not used to choosing a topic based on their own judgment and interest, as they had apparently hoped to simply pick a topic from existing research questions.’ (TF, S.1)
Difficulties in self-directing learning processes	Situations in which students’ problems with carrying out a learning step in a self-directed manner could be observed.	(i) ‘[The students said:] ‘What, literature sources? But we’re looking for them together now, aren’t we?’ – [And I said:] ‘No, we’re not looking for them together. You go looking for them yourselves.’ [...] I think it’s difficult for them to act on their own. Or at least that’s my impression [...] And I didn’t get them to switch to independent work.’ (FGD 2)
(Perceived) overwhelm with learning steps	Situations in which students appeared to be or feel overwhelmed with required learning steps.	(j) ‘Despite the references to the [online learning platform] and the internet, some students did not feel able to find a starting point for themselves at first, so

		that each [of them] had to be addressed individually.’ (TF, S.6)
Motivational difficulties	Situations in which motivational difficulties among the students could be observed.	<p>(k) ‘Grumbling, discussions, resistance to homework [...] - Statement by a student: ‘I know my research topic already, that’s why I didn’t create a mind map’.’ (PO, S.3)</p> <p>(l) ‘When it came to revising the research question again, the motivation of some students waned as they thought they already had a good question.’ (TF, S.5)</p>
<b><i>Overarching context factors</i></b>		
Time for learning processes	Situations in which insufficient time provided for the students to carry out a learning step was identified as a problem.	(m) ‘Important insight: Time for own research is really important! Concrete situation here: The research phase between [sessions 3 and 4] planned in the redesign did not take place here for [organisational] reasons. In discussions with individual students, it then became clear that they found it difficult to narrow down the topic further due to a lack of [familiarisation with their topics]!’ (Participant observation [PO], S.4)
Teacher support	Situations showing students’ need for (stronger) support by the teacher and/or indicating that the teacher him- or herself needed support to guide his or her students.	<p>(n) ‘For some [students], very targeted individual guidance is necessary. In some cases, specific instructions are also required. Only motivated and interested students can approach their topic through this free development without receiving direct ‘input’ from the teacher.’ (TF, S.1)</p> <p>(o) ‘A pool of research questions that have already been worked on would help me enormously to be able to better assess the students’ research questions. You would then perhaps also get ideas for further topics and formulations.’ (TF, S.6)</p>

Heterogeneity	Situations in which the heterogeneity of the learning group (e.g., regarding motivational dispositions, learning performance, prior knowledge or self-direction abilities) was identified as a challenging factor.	(p) ‘Well, I have some really excellent people in there. A very, very large midfield, who are already doing good research [...]. And then I have two students who have actually done nothing so far.’ (FGD 2)
Organisational /infrastructural aspects	Situations in which organisational or infrastructural factors were observed to affect the students’ learning processes.	(q) ‘We probably all have [the seminar] in the [...] afternoon. And when they actually needed time to complete the task nicely, because it was a nice task, they didn't really feel like doing it anymore because it was so late, that was a bit of a problem.’ (FGD 2)  (r) ‘[Social interaction] very limited due to digital implementation => Breakout sessions did not work for technical reasons => Individual work from this point on.’ (PO, S.2)

### ***Didactic approaches to address the challenges***

Several targeted support measures proved effective in dealing with these challenges. Table 3 presents a matrix linking core problems (right columns) to suitable didactic approaches (left column). For better clarity, the many individual support measures implemented within the learning environment were summarised thematically. Some of these measures were implemented only after the second main cycle and could not yet be evaluated individually. Nevertheless, the *overarching* approaches listed here could all be confirmed as effective in general across both cycles. It should be noted that all these measures are always context-dependent – accordingly, they work better with some teachers and in some groups of students,

particularly when teachers and/or students already had prior experience with open, inquiry-oriented formats.

To reference the approaches with the learning steps of the final learning environment in which they are realised, the bold numbers in square brackets correspond to the numbers of the individual learning steps in Table 1 (e.g.: The approach ‘Explication of students’ interests’ is applied in learning steps 1, 3 and 4). Context factors were excluded from the matrix.

**Table 3.** Overview of the didactical approaches to address the identified challenges during the question development and research planning phase (Bold numbers in square brackets correspond to the numbers of the individual learning steps in Table 1. Tick marks indicate an influence of a measure on a certain challenge. Tick marks in brackets indicate the indirect influence of support measures for teachers on the challenges faced by students.).

POTENTIAL CHALLENGES DURING THE QUESTION DEVELOPMENT AND RESEARCH PLANNING PHASE

	Missing knowledge about / experience with research	Insufficient underst. of funct. / goals of lear. steps	Missing / deficient heuristics for learning steps	Uncertainties in the planning of research processes	Problems with cooperative activities	Difficulties to become aware of and pursue own interests	Difficulties in self-directing learning processes	(Perceived) overwhelm with learning steps	Motivational difficulties
Preview and discussion of question development and research planning phase [1]	✓	✓		✓			✓		✓
Advance organizer to make learning steps transparent [1,3,4,6,8,10,12,14]	✓	✓					✓		✓
Preparatory discussion of learning steps and/or associated materials [1,6,10,12]	✓	✓	✓				✓	✓	
Explication of students' interests [1,3,4]						✓			✓
Formulation of learning tasks: Precise, comprehensible, vivid, linked to students' expectable knowledge, picking up students' individual ideas [3,5,7,8]	✓	✓	✓		✓	✓	✓	✓	✓
Provision of clear guidelines, criteria, scaffolds and/or heuristics [4,5,6,7,8,10,12,13]	✓	✓	✓		✓		✓	✓	✓
Vivid examples for intended products of learning steps [1,4,7,8,10,12,13]	✓	✓	✓		✓		✓	✓	✓
Individual homework phases for students to engage with their topics [5,7]	✓					✓	✓		
Occasions to practice cooperative activities [4,9,12]					✓		✓		
Instructions, notes, suggestions, and information materials for teachers [1-14]	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
Adequate structuring of the learning steps (order, duration, and distribution over the sessions) [1-14]		✓					✓	✓	✓

APPROACHES TO ADDRESS THE IDENTIFIED CHALLENGES

To illustrate how these results were achieved, selected findings will be elucidated in an exemplary manner in the following.

### *Integration of an initial overview session and an advance organiser*

Data from the first cycle showed the importance of helping students understand the succession and functions of the learning steps even better. Therefore, from cycle two onward, the question development began with a preview and discussion of the phase's goals and the upcoming learning steps (learning step 1). An information sheet outlining the learning steps was also introduced and used as an advance organiser at the start of each session (learning steps 1, 3, 4, 6, 8, 10, 12, 14). Data from cycle two confirmed the high effectiveness of this measure.

### *Provision of clear criteria, templates and examples for learning steps*

To support students in understanding the goals of key tasks – such as formulating a research question or designing a method – it proved helpful to provide clear criteria, templates, and examples. For instance, a sample mind map supported thematic exploration (step 4), while provided quality criteria guided question development (step 6).

To further clarify objectives, additional improvements were made during the two cycles, including the use of negative examples for orientation and more specific examples for method design.

### *Cooperative learning activities*

From the outset, the concept included cooperative activities such as peer reviews of mind maps (step 4) and research questions (step 8). While both research cycles revealed student difficulties with these formats, observations and teacher feedback showed they effectively supported individual research planning and promoted self-direction and self-assessment. Therefore, cooperative phases were maintained and expanded, including peer feedback for method design (step 12). At the same time, giving and receiving

feedback remained a persistent challenge for many students despite these improvements, which is why teachers were encouraged to practice techniques of constructive feedback and discuss its purpose on a meta-level with their students.

### *Support for teachers*

It became evident that teachers played a crucial role for the success of students' learning processes. In addition to a three-day training, teachers received a detailed manual explaining each learning step and offering instructions, suggestions, and background information. However, observations and feedback revealed that many teachers still faced challenges in guiding complex IBL processes and needed more specific or extensive support in research-related content, procedural, and organisational competencies, in identifying and responding to students' research-specific difficulties, in certain classroom management and communication strategies, as well as in constructive, student-centered interaction styles regarding research processes. These challenges had a significant impact on student learning. In response, the manual was expanded over both research cycles to include:

- Step-by-step guidance and suggestions for student support
- Orientation materials on goals and expected outcomes
- Task-specific horizons of expectation
- Conversation prompts and learning impulses
- Alternative strategies for implementing steps

As Table 3 shows, these teacher-focused measures indirectly address all identified student challenges.

## **Discussion**

Using the example of our learning environment, we systematically identified central challenges arising in the question development and research planning phase of IBL. Existing empirical findings were confirmed: Motivation, self-organisation, and sufficient time remain key success factors for formulating research questions and planning research projects. Our data further underscore the role of prior knowledge – students often lack the experience necessary to engage meaningfully in authentic research (cf. Heidinger, 2016; Sievers & Westphal, 2018). We were able to specify the resulting difficulties in more detail.

Among all learning steps, developing a research question proved especially challenging. This likely stems from the abstract nature of this task and the required iterations to narrow broad interests into a precise, researchable question.

A key conclusion is that many of the observed difficulties stem from the unfamiliarity of IBL's working logic, content, methods, and epistemology. This is obviously embedded in a larger context. At least at the schools included in the study, the students' previous learning habits and their school socialisation did not fully match the working methods typical of IBL.

Many students were only to a limited extent familiar with open-ended, creative work and cooperative learning that depends on individual judgment – despite such formats being central to constructivist pedagogy (Reinfried, 2007) that is taught in teacher training programs at universities in Bavaria. Thus, to enable authentic IBL in line with scientific practice, such learning forms must be integrated into learning environments and ideally introduced early in students' school careers to foster the necessary competencies cumulatively (van Joolingen et al., 2007).

This shift requires supportive curricular and structural conditions in schools, particularly time and flexibility. At the same time, our data confirm the central role of

teachers in IBL – echoing earlier studies (Alfieri et al., 2011; Furtak et al., 2012; Lazonder & Harmsen, 2016). Students need targeted guidance, and teachers often struggle to provide it. These difficulties are well-documented: the teacher’s role in IBL differs significantly from traditional instruction. Rather than transmitting knowledge, teachers act as mentors (Beyerlin et al., 2020; Scholkmann, 2020) – a role for which many have not been trained (Popov & Tevel, 2007; Capps & Crawford, 2013; Gilbert, 2009; Khalaf & Zin, 2018).

Moreover, effective facilitation of IBL requires not just subject knowledge, but also procedural and epistemic knowledge (Banerjee, 2010), strong classroom management, and the ability to build positive, supportive relationships (Quigley et al., 2011). Teacher training programs that neglect research-related competencies may therefore hinder effective IBL (Dorier & García, 2013).

Given that these structural prerequisites are not yet established in Bavarian schools, a second conclusion follows: the design of IBL environments must provide didactic solutions that enable students to develop research questions, methodical designs, and research plans – even under existing conditions. Our results show that with targeted, differentiated support, students can succeed in this demanding phase.

This study contributes to didactic theory by addressing a research gap: Until now, few studies have detailed effective approaches for guiding students in developing their own research questions and designs (Rönnebeck et al., 2016). Based on our IBL environment, we developed and partially validated a set of didactical strategies to support this phase. These approaches can be used as design elements in future IBL environments to anticipate and mitigate typical challenges.

The findings also lay the groundwork for future research. Quantitative studies could test hypotheses and variables derived from the identified challenges and didactic approaches to assess their effectiveness more systematically.

Further, future research could focus on examining in greater detail the conditions under which certain didactic support approaches are effective: in other words, when, in which contexts and for whom certain approaches work and when they do not.

### ***Limitations***

The results emerged from a specific learning environment. Some challenges may have been shaped by its structure; different formats might reveal different or additional issues. For example, excluding cooperative phases in favor of stronger teacher control might prevent some problems while introducing others. Future research should examine the transferability of these findings to other contexts.

The study was conducted in Germany and the state of Bavaria, where teacher training and student learning habits may differ from other regions – limiting generalisability of the findings.

Learning outcomes were not evaluated by competency tests. Instead, learning success was assessed through in-depth process observation by researchers and teachers. Future research could include systematic analyses of student products to evaluate learning more directly.

Finally, the didactic measures developed after the second research cycle were not subjected to further empirical validation. While feedback from teachers in subsequent implementations suggests certain additions – like a sample video for literature research or a restructured lesson for planning – were helpful, these measures remain potentially effective and should be investigated further.

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#### 4.4 Überblick über die Eigenbeiträge der Autor:innen zu den kumulierten Publikationen

In Tabelle 1 sind die Einzelbeiträge der an den Publikationen beteiligten Autor:innen aufgeschlüsselt. Das Kürzel SB steht dabei für Sebastian Brumann, den Autor dieser Dissertation. UO steht für Ulrike Ohl, CS für Carolin Schackert und JS für Johannes Schulz.

**Tabelle 1: Überblick über die Eigenbeiträge der Autor:innen zu den kumulierten Publikationen**

	<b>Beitrag 1</b>	<b>Beitrag 2</b>	<b>Beitrag 3</b>
Konzeptualisierung	SB, UO, CS	SB, UO, JS	SB
Methodik	-	SB, UO	SB
Datenerhebung / Recherche	SB, UO, CS	SB, JS	SB
Datenaufbereitung	-	SB	SB
Datenanalyse	-	SB	SB
Validierung	-	SB, UO, JS	SB, JS
Verfassen – Erstentwurf	SB, UO, CS	SB	SB
Verfassen – Überarbeitung und Redaktion	SB, UO, CS	SB, UO, JS	SB, UO
Visualisierung	SB	SB	SB
Einwerbung von Fördermitteln	UO, SB	UO, SB	UO, SB
Projektadministration	SB	SB	SB
Betreuung / Supervision	UO	UO	UO

## 5 Diskussion und Ausblick

Die Forschungsfelder zu Forschendem Lernen bzw. IBL sowie zur Climate Change Education werden auch gegenwärtig intensiv bearbeitet. Insbesondere die Verbindung beider Ansätze im Sinne der Diskussion und Nutzbarmachung der Potentiale Forschenden Lernens für die Climate Change Education zeigt in jüngster Zeit eine erfreuliche Dynamik (siehe z.B. Ballard et al., 2024; Batchelder et al., 2023; Erenler et al., 2025; Meixner et al., 2023; Parth et al., 2024). Zu diesen Diskursen konnte das vorliegende Dissertationsprojekt durch die Erkenntnisse der drei Einzelstudien einen wertvollen Beitrag leisten.

## 5.1 Zusammenfassende Diskussion der Erkenntnisse und wissenschaftlicher Beitrag

Ausgangspunkt war die zielgerichtete Literaturanalyse in Beitrag 1, die als Grundlage für die eigenen empirischen Zugänge systematische Erkenntnisse hinsichtlich der bis dato empirisch und theoretisch beschriebenen Potentiale Forschenden Lernens für die CCE hervorbrachte. Durch die Ableitung erster Designprinzipien und deren Operationalisierung in einem ersten Entwurf der Lernumgebung erfüllte diese erste Studie eine Pilotfunktion und bildete zugleich das Fundament für die folgenden Forschungsschritte.

In der in Beitrag 2 vorgestellten Studie wurde untersucht, wie ein wissenschaftspropädeutisches Seminar zu regionalen Implikationen des Klimawandels in der gymnasialen Oberstufe konzipiert sein sollte, um erfolgreiche Lernprozesse in einem wissenschaftsnahen Ansatz Forschenden Lernens zu unterstützen. Dazu wurde als theoretischer Forschungsausgangspunkt ein Katalog zentraler Gestaltungsprinzipien entwickelt und ausdifferenziert, die auf drei unterschiedlich konkreten Operationalisierungsebenen angesiedelt sind. Die herausgearbeiteten Designprinzipien zeigen vor allem auf den beiden oberen, abstrakteren Ebenen theoretische Einsichten, die in gewissem Maße als übertragbar betrachtet werden können. Ihre Anwendung ermöglicht es, wissenschaftsnahes Forschendes Lernen in der gymnasialen Oberstufe in vergleichbaren Bildungskontexten umzusetzen. Da diese Prinzipien einen Gestaltungsrahmen bereitstellen, der außerhalb des Hochschulkontextes bislang fehlte, können sie als Grundlage für eine gezielte wissenschaftspropädeutische Bildung an Schulen dienen, die auf den Erwerb von *Scientific Literacy* und weiteren wissenschaftsbezogenen Kompetenzen abzielt (vgl. etwa OECD, 2017; Gess et al., 2017). Zudem konnte die Studie auf der konkretesten Ebene der zielgruppenspezifischen Operationalisierung Prinzipien herausarbeiten, die zugleich detaillierte, kontextspezifische Handlungsanleitungen („How-to-Guidelines“) für die Gestaltung wissenschaftsnaher IBL-Umgebungen zum Thema Klimawandel darstellen. Darüber hinaus liefert die im Verlauf des DBR-Prozesses entwickelte finale Lernumgebung einen wertvollen praktischen Forschungsausgangspunkt, da sie für die schulische Praxis in einem unmittelbar einsetzbaren Format zur Verfügung steht. Bezieht man alle Forschungszyklen und darauffolgenden Anwendungen mit ein, dann kam die Lernumgebung bis dato

(Stand 2025) in über 90 Schulen zum Einsatz und wurde von mehr als 1.000 Schüler:innen durchlaufen. Besonders erfreulich waren dabei zahlreiche Preisgewinne von Schüler:innen, die mit ihren aus dem W-Seminar hervorgegangenen Arbeiten bei Wissenschaftswettbewerben („Jugend forscht“, „Hans-Riegel-Fachpreise“) teilgenommen haben. Die Lernumgebung wurde in Form eines umfassenden Manuals für Lehrkräfte inklusive detaillierten Stundenverlaufsplänen, Arbeitsmaterialien, Informationsressourcen, Tipps und Hinweisen sowie theoretischen Hintergründen zum forschenden Lernen publiziert (Brumann et al., 2022a; siehe Anhang 1). Begleitend zur Entwicklung der Lernumgebung wurde auch eine dreitägige Lehrkräftefortbildung als Einführung in das Konzept entwickelt und über sechs Jahrgänge hinweg an der Akademie für Lehrkräftefortbildung und Personalführung (ALP) in Dillingen durchgeführt, wodurch mehr als 100 Lehrkräfte erreicht werden konnten. Die Fortbildung wurde in allen Jahrgängen sehr gut evaluiert, wobei von den teilnehmenden Lehrkräften wiederholt betont wurde, wie hilfreich das Konzept auch für die Durchführung inhaltlich anders ausgerichteter W-Seminare im Modus des Forschenden Lernens ist.

Die dritte Studie (Beitrag 3) vertiefte schließlich die Analyse, indem sie den Fokus auf die Phase der Fragefindung und Forschungsplanung legte, die in der Forschungsliteratur als besonders neuralgisch beschrieben, hinsichtlich ihrer spezifischen Herausforderungen jedoch bislang nicht hinreichend differenziert analysiert wurde (vgl. Heidinger 2016; Sievers & Westphal 2018; Rönnebeck et al., 2016). Die Studie identifiziert anhand der in Beitrag 2 entwickelten Lernumgebung systematisch zentrale Schwierigkeiten, die in dieser Phase Forschenden Lernens auftreten. Dadurch konnten einerseits bereits vorliegende empirische Befunde bestätigt werden: Motivation, Selbstorganisation und ausreichend Zeit bleiben Schlüsselfaktoren für die Formulierung von Forschungsfragen und die Planung von Forschungsprojekten. Die Daten unterstreichen zudem die Rolle des Vorwissens: Viele der beobachteten Schwierigkeiten konnten auf eine mangelnde Vertrautheit der Schüler:innen mit der Arbeitslogik, den Inhalten, den Methoden und der Epistemologie von Forschendem Lernen zurückgeführt werden. Vor allem die daraus resultierenden Schwierigkeiten konnten in der Studie detaillierter spezifiziert werden. Diese Defizite hängen eng mit den bisherigen Lerngewohnheiten und der schulischen Sozialisation zusammen, die nur begrenzt

auf offene, kreative, eigenverantwortliche und kooperative Arbeitsformen vorbereiten. Damit authentisches, wissenschaftsnahes Forschendes Lernen gelingt, müssen solche Lernformen frühzeitig eingeführt und in Lernumgebungen systematisch verankert werden. Dies setzt zugleich förderliche curriculare und strukturelle Rahmenbedingungen wie ausreichend Zeit und Flexibilität voraus. Da diese strukturellen Voraussetzungen in bayerischen Schulen bislang nicht gegeben sind, ergibt sich aus der Studie eine weitere zentrale Erkenntnis: Die Gestaltung von IBL-Umgebungen muss didaktische Lösungen bereitstellen, die es Schüler:innen ermöglichen, Forschungsfragen, methodische Designs und Forschungspläne auch unter bestehenden Bedingungen zu entwickeln. Im Rahmen der Studie konnte ein Set an didaktischen Strategien entwickelt und teilweise validiert werden, mit deren Hilfe Schüler:innen auch in dieser anspruchsvollen Phase erfolgreich sein können. Diese Ansätze können künftig als Gestaltungselemente in IBL-Umgebungen dienen, um typische Herausforderungen vorwegzunehmen und abzumildern. Da es bislang nur wenige Studien gibt, die effektive Ansätze zur Unterstützung von Schüler:innen bei der Entwicklung eigener Forschungsfragen und Designs detailliert beschreiben (Rönnebeck et al., 2016), leistet die Studie damit einen Beitrag zur Didaktik, indem sie diese Forschungslücke adressiert.

Als eines der zentralsten Ergebnisse vor allem des zweiten und dritten Beitrags lässt sich übergeordnet feststellen, dass die Lehrkräfte im wissenschaftsnahen Forschenden Lernen an Schulen einen entscheidenden Einflussfaktor für den Erfolg der Lernprozesse darstellen – dies steht auch im Einklang mit früheren Studien (Alfieri et al., 2011; Furtak et al., 2012; Lazonder & Harmsen, 2016). Die erhobenen Daten zeigen, dass Forschendes Lernen in vielen Dimensionen der professionellen Lehrkräftekompetenz hohe Anforderungen – insbesondere an Fachwissen und fachdidaktisches Wissen (vgl. Kunter, 2011; Kunter et al., 2009) – stellt, die weit über das hinausgehen, was üblicherweise von Lehrkräften im schulischen Kontext verlangt wird. Ein möglicher Ansatz zur Bewältigung dieser Herausforderungen könnte in einer breiteren Integration von Forschendem Lernen in die universitäre Lehrerbildung bestehen, wie etwa von Huber (2009) oder Fichten (2013) gefordert. Forschendes Lernen in der Lehrkräftebildung kann nicht nur spannend und motivierend sein, sondern auch Erfahrungen generieren, von denen Studierende später profitieren. Lehrkräfte, die in ihrer Ausbildung selbst Daten erhoben und analysiert haben und im besten Fall auch die Möglichkeit hatten, über

die *Nature of Science* zu reflektieren, können diese Kompetenzen in der Arbeit mit ihren Schüler:innen gewinnbringend einsetzen.

Darüber hinaus erfordert Forschendes Lernen erweiterte Fähigkeiten im Bereich des „Teacher Noticing“ (vgl. Bastian et al., 2021), da es im Verlauf von IBL-Prozessen zahlreiche Situationen gibt, in denen ad-hoc-Unterstützung durch die Lehrkraft notwendig wird. Dies verlangt sowohl eine geschulte Wahrnehmung der Unterstützungsbedarfe von Lernenden als auch eine angemessene Reaktion darauf. Über die Dimension professioneller Kompetenzen hinaus haben wir aus dem Feedback der Lehrkräfte erfahren, dass sie sich teils auch in der veränderten Rolle unwohl fühlten. In wissenschaftsnahem forschendem Lernen sind Lehrkräfte nicht allwissende Wissensvermittler:innen und Dirigent:innen der Lernprozesse, sondern vielmehr Coaches und Lernbegleiter:innen auf Augenhöhe mit den Schüler:innen (Wulf, 2017; Beyerlin et al., 2020; Scholkmann, 2020; Sonntag et al., 2016) und damit Teil eines Forschungs- (und Lern-)kollektivs. Dies stellt eine Rolle dar, auf die viele Lehrkräfte durch ihre Ausbildung und beruflichen Erfahrungen nicht hinreichend vorbereitet sind (Popov & Tevel, 2007; Capps & Crawford, 2013; Gilbert, 2009; Khalaf & Zin, 2018). Vor diesem Hintergrund erscheint ein Wandel von noch weit verbreiteten transmissiven Lernverständnissen hin zu einer stärker konstruktivistischen Perspektive notwendig. Gerade im IBL-Kontext könnten dabei Ansätze wie *Knowledge Building* vielversprechend sein (Scardamalia, 2002; Scardamalia & Bereiter, 2006; Bereiter & Scardamalia, 2014).

## 5.2 Limitationen der Arbeit

Zentrale Limitationen des Forschungsprojekts ergeben sich aus dem gewählten „Design-based Research“-Ansatz. DBR zielt auf die Entwicklung eines komplexen Sets an Designprinzipien als theoretischem Output ab und ist daher naturgemäß nicht geeignet, isolierte Variablen zu identifizieren. Kausalaussagen im Format „x führt zu y“ sind nicht möglich, da die angewandten Designprinzipien stets als Ganzes zusammenwirken, um ein bestimmtes Ergebnis zu erzielen. Gleichzeitig ermöglicht dieser Ansatz jedoch, möglichst viele potentiell relevante Kontextfaktoren umfassend zu berücksichtigen und damit eine Lernumgebung zu schaffen, die in ihrer Gesamtheit gewünschte Effekte erzielt. Da sich diese Faktoren

darüber hinaus detailliert sowohl als Einzelaspekte als auch in ihrem Zusammenspiel beschreiben lassen, ergibt sich daraus vor allem in explorativen Forschungsprojekten ein großer Vorteil.

Berücksichtigt man die zentrale Bedeutung der Lehrkraft, die sich im Rahmen der Studien zeigte, dann wird klar, dass auch vor diesem Hintergrund DBR gewisse Grenzen hat. Die Möglichkeiten des Ansatzes, diesen Faktor zu adressieren, beschränken sich überwiegend auf das Design der Lernumgebung, während beispielsweise die Lehrerbildung kaum beeinflusst werden kann. Dennoch konnten wir durch den DBR-Prozess auch Stellschrauben identifizieren, durch die Lehrkräfte bestmöglich bei der Begleitung der Lernprozesse der Schüler:innen unterstützt werden können. Diese wurden in der Lernumgebung sowie im begleitenden Manual operationalisiert und zusätzlich in ergänzende Maßnahmen wie etwa die erwähnte Lehrkräftefortbildung integriert.

Mit seinem iterativen Charakter wirft DBR zudem die Frage auf, wann eine Konzeption und die jeweiligen Designprinzipien als „final“ betrachtet werden können. Theoretisch gilt: Je mehr Iterationen durchgeführt werden, desto differenzierter wird das Ergebnis. Im vorliegenden Projekt haben wir den Forschungsprozess aus zwei Gründen nach einem Pilotzyklus und zwei Hauptforschungszyklen abgeschlossen: Erstens erfüllt unsere Konzeption vier grundlegende Kriterien, die in der Praxis üblicherweise die Anzahl der Iterationen bestimmen (Nieveen, 2010; Plomp, 2010): Sie basiert auf dem aktuellen Stand der Forschung (Inhaltsvalidität), ihre Bestandteile sind logisch und kohärent miteinander verknüpft (Konstruktvalidität), die Endnutzer:innen können sie so anwenden, wie es im Sinne der Zielsetzung intendiert war (Praktikabilität), und sie führt zu den angestrebten Lernergebnissen (Wirksamkeit). Zweitens wäre eine stetige Anpassung immer neuer Details irgendwann nicht mehr praktikabel, da ab einem gewissen Punkt lediglich auf die individuellen Merkmale und Bedürfnisse der jeweils beteiligten Lerngruppe reagiert würde – mit anderen Worten: Selbst wenn die Lernumgebung insgesamt in einen optimalen Zustand überführt wird, wird es stets einen Spielraum für Verbesserungen im Hinblick auf spezifische Lerngruppen geben.

Unsere Beobachtungen zeigen zwar, dass die entwickelte Lernumgebung Dispositionen für klimaschutzbezogenes Handeln bei den Schüler:innen fördern

kann, jedoch sind bislang keine gezielten didaktischen Elemente integriert, die Handlungskompetenzen systematisch adressieren. Ansätze, um diese Dimension aufzugreifen, sind Gegenstand eines aktuellen Forschungsprojekts des Lehrstuhls. Ferner fehlen bisher Forschungsergebnisse zum regionalen und individuellen Zugang, der für unsere Konzeption zentral ist. Die Idee, dass Schüler:innen in ihrer unmittelbaren Umgebung, in ihrem eigenen Alltag und orientiert an ihren individuellen Interessen forschen, stellt ein Kernelement unserer Lernumgebung dar. Laut Forschungsliteratur sind mit diesen Merkmalen sehr wahrscheinlich Effekte verbunden, die im Kontext von CCE wünschenswert sind (z. B. Verringerung der psychologischen Distanz oder Förderung von Conceptual Change). In unserem Forschungsprojekt haben wir diese theoretischen Zusammenhänge als grundlegende Annahmen aufgenommen, auf deren Basis wir die Konzeption entwickelt haben. Dennoch erscheint es vielversprechend, durch gezielte Forschungsansätze zu prüfen, inwieweit unsere Lernumgebung tatsächlich zu solchen Effekten beiträgt. Gleiches gilt für die Perspektiven der Schüler:innen, die bislang nur indirekt über die Beobachtungen der Lehrkräfte erfasst wurden. Damit ist noch nicht abschließend geklärt, wie sich die Lernumgebung auf Motivation, Interessen und die Bereitschaft zu umweltfreundlichem Verhalten auswirkt. Zukünftige Forschung sollte sich daher verstärkt diesen Aspekten widmen. Ebenso wurde der Lernerfolg nicht über Kompetenztests erhoben, sondern über detaillierte Prozessbeobachtungen durch Forschende und Lehrkräfte erfasst. Künftige Studien könnten etwa systematische Analysen von Schülerprodukten einbeziehen, um Lernergebnisse direkter zu evaluieren.

Die eingesetzte Methode der teilnehmenden Beobachtung wirft die Frage auf, inwieweit die Anwesenheit der Beobachtenden und ihre Interaktion mit den Schüler:innen Reaktivitätseffekte verursacht haben könnten. Für den Pilotzyklus lässt sich dies nicht ausschließen, da in dieser Phase häufigere Interaktionen erforderlich waren, um herauszufinden, welche spezifischen Unterstützungsmaßnahmen die Schüler:innen benötigen. Für die Hauptzyklen – insbesondere Zyklus 2 – können solche Effekte jedoch als sehr unwahrscheinlich angesehen werden, da die Interaktion zwischen Forschenden und Schüler:innen auf Small Talk oder organisatorische Fragen beschränkt war.

Zu Beitrag 3 sollte zusätzlich angemerkt werden, dass die nach dem zweiten Forschungszyklus entwickelten didaktischen Maßnahmen keiner weiteren empirischen Validierung unterzogen wurden, da der darauffolgende dritte Anwendungszyklus der Lernumgebung nicht mehr systematisch beforscht wurde. Zwar deutet das Feedback der Lehrkräfte in späteren Umsetzungen darauf hin, dass bestimmte Ergänzungen – etwa ein Beispielvideo zur Literaturrecherche oder eine umstrukturierte Unterrichtsstunde zur Planung der Fragefindungs- und Forschungsplanungsphase – hilfreich waren. Dennoch kann diesen Maßnahmen dadurch bislang lediglich eine potentielle Wirksamkeit attestiert werden, welche in weiteren Studien untersucht werden sollte.

Die im Forschungsprojekt entwickelten Designprinzipien als theoretische Basis für die Operationalisierung von Lernumgebungen erlauben zwar eine gewisse Übertragbarkeit in vergleichbare Bildungskontexte. Da das Projekt explizit auf wissenschaftsnahes Forschendes Lernen fokussiert, können diese Designprinzipien und die daraus resultierende Lernumgebung ihre volle Wirkung jedoch nur in didaktischen Arrangements entfalten, die hierfür die nötigen Rahmenbedingungen bereitstellen. Solche zeitlichen und organisatorischen Rahmenbedingungen finden sich insbesondere im projektorientierten Unterricht. Darüber hinaus ist anzumerken, dass die Ergebnisse – vor allem jene des dritten Forschungsbeitrags – einer spezifisch gestalteten Lernumgebung entstammen. Daher könnten manche der identifizierten Herausforderungen durch die Struktur der Lernumgebung geprägt sein, während andere Formate unterschiedliche oder zusätzliche Probleme aufzeigen könnten. So wäre es durchaus denkbar, dass etwa der Verzicht auf kooperative Phasen zugunsten stärkerer Steuerung durch die Lehrkraft manche Schwierigkeiten verhindern, zugleich aber auch neue hervorrufen könnte. Zukünftige Forschung sollte daher die Übertragbarkeit dieser Befunde auf andere Kontexte prüfen. Eine zusätzliche Einschränkung der Generalisierbarkeit der Ergebnisse kann sich potentiell aus der Durchführung der Studien in Deutschland, konkret in Bayern, ergeben, da sich dort sowohl Lehrkräftebildung als auch Lerngewohnheiten der Schüler:innen von anderen Regionen unterscheiden können.

### 5.3 Ausblick auf weiterführende Forschungspotentiale

Wie bereits vor dem Hintergrund der Limitationen deutlich wurde, bilden die Studien mit ihren umfassenden, qualitativ erarbeiteten Ergebnissen vor allem eine ideale Grundlage für darauf aufbauende quantitative Zugänge. So erscheint etwa ein Zugang mit standardisierten Instrumenten sehr vielversprechend, um den Erwerb intendierter Kompetenzen bei Schüler:innen, die mit der entwickelten IBL-Umgebung arbeiten, zu erfassen. Dies bietet sich in besonderem Maße einerseits für wissenschaftsbezogene Kompetenzen an, wie sie beispielsweise Willison & O'Regan (2007; 2006/2012) in ihrem "Research Skill Development Framework", die OECD (2017) im Konstrukt der „Scientific Literacy“ oder auch Gess et al. (2017) in ihrem Modell von „Forschungskompetenz“ beschreiben – und andererseits für klimabezogene Kompetenzen, zum Beispiel im Rahmen der „Climate Literacy“ (Azevedo & Marques, 2017). Auf der Hand lägen hierfür etwa Kompetenztests nach dem Durchlaufen ausgewählter Lernschritte oder nach Seminarabschluss. Auch systematische Analysen von Schülerprodukten bieten sich an, um Lernergebnisse direkter zu evaluieren – beispielsweise die individuell formulierten Forschungsfragen der Schüler:innen, die „Forschungslogbücher“, mit denen sie ihren Forschungsprozess dokumentieren, oder die schriftlichen Seminararbeiten. Längsschnittliche Designs könnten zudem dazu beitragen, die Nachhaltigkeit der Effekte auf erworbene Kompetenzen und damit auch langfristige Wirkungen Forschenden Lernens zu untersuchen. Überdies könnten die Wirkungen der Lernkonzeption auf weitere für die CCE relevante Konstrukte untersucht werden – beispielsweise die Verringerung psychologischer Distanz, die Förderung von Conceptual Change, die Steigerung kritischer Denkfähigkeiten oder Effekte auf Interesse und Motivation der Schüler:innen. Mit Blick auf die in Beitrag 3 identifizierten Herausforderungen in der Fragefindungs- und Forschungsplanungsphase könnten quantitative Studien sowohl dabei helfen, auftretende Lernschwierigkeiten zu quantifizieren, als auch durch die isolierte Betrachtung von Variablen auf einzelne Faktoren zurückzuführen. Analog dazu ließe sich die Wirksamkeit didaktischer Ansätze zur Adressierung solcher Lernschwierigkeiten systematisch evaluieren.

Über solche quantitativen Ansätze hinaus bietet es sich an, die Übertragbarkeit des entwickelten Konzepts auf andere Kontexte zu prüfen, etwa auf unterschiedliche

Schulfächer, andere Bundesländer oder internationale Settings. Eine gute Basis hierfür bilden die im Rahmen des Forschungsprojekts erarbeiteten Designprinzipien, vor allem auf den beiden oberen, abstrakteren Operationalisierungsebenen, aus denen sich konkrete Umsetzungsmöglichkeiten für den jeweiligen Anwendungsfall ableiten lassen.

Gerade vor dem Hintergrund der wichtigen Erkenntnis, dass viele Herausforderungen beim Forschenden Lernen in der Oberstufe auf einen Mangel an Vorwissen bzw. -erfahrung mit vergleichbaren Lernformen zurückzuführen sind, scheint es besonders lohnenswert, den Fokus auf den kumulativen Erwerb forschungsbezogener Kompetenzen auszuweiten. Einerseits bietet es sich z.B. an, durch die Operationalisierung bestehender Stufenmodelle – wie etwa das „Research Skill Development Framework“ (Willison & O’Regan, 2007; 2006/2012) – zu untersuchen, wie einfache Formen Forschenden Lernens bereits in früheren Bildungsstufen wirksam gestaltet werden können. Andererseits scheint auch ein Vergleich der forschungsbezogenen Kompetenzen von Oberstufenschüler:innen zwischen Systemen mit unterschiedlichen curricularen Rahmenbedingungen sinnvoll: Ausprägtere Kompetenzen bei Schüler:innen, die bereits Forschungserfahrung in jüngeren Altersstufen sammeln konnten, liegen nahe. Solche Ausgangslagen ließen sich potentiell etwa in den USA mit den bereits erwähnten „National Science Education Standards“ (National Research Council, 1996; 2000; 2012) finden – aber auch in Deutschland gibt es zumindest vereinzelt Schulen, die ihren Schüler:innen z.B. durch die gezielte und strukturierte Vorbereitung auf Wissenschaftswettbewerbe bereits ab Beginn der Sekundarstufe eine frühe Förderung wissenschaftlicher Kompetenzen angedeihen lassen.

#### 5.4 Abschließende Gedanken

Zu Beginn unseres Forschungsprojekts im Jahr 2018 war zunächst nicht klar, inwiefern sich ein so umfassendes und anspruchsvolles wissenschaftsnahes Forschendes Lernen tatsächlich auch im Schulkontext erfolgreich anwenden lässt. Vor dem Hintergrund aller weiter oben bereits beschriebenen Rahmenbedingungen und Herausforderungen durfte dieses Vorhaben als ambitioniert gelten. Das immense didaktische Potential lag jedoch zugleich auf der Hand und DBR bot sich als idealer Forschungsansatz an, Fehler und Umwege von Anfang an in den Forschungsprozess einzukalkulieren – mehr noch: daraus zu lernen und wertvolle

Schlüsse für die Optimierung der zu entwickelnden Lernumgebung abzuleiten. So lässt sich rückblickend festhalten, dass unsere Forschungsergebnisse zwar deutliche Grenzen und Hürden für Forschendes Lernen in der gymnasialen Oberstufe offenbart haben, gleichzeitig jedoch auch ein umfassendes didaktisches Instrumentarium zur erfolgreichen Implementierung des Ansatzes entwickelt werden konnte. Doch nicht nur anhand der erhobenen Daten lässt sich der Erfolg dieser Implementierung nachzeichnen: Die vielfältigen und spannenden Forschungsprojekte mehrerer Generationen teilnehmender Schüler:innen so intensiv begleiten zu können, die mit Begeisterung, Eifer, Neugier und Kreativität nicht nur in die Rolle von Forschenden schlüpfen, sondern oftmals neue, auch für Dritte bedeutsame und bisweilen sogar mit Wissenschaftspreisen ausgezeichnete Erkenntnisse generierten – kurz: junge Menschen beim „Schauen und Begreifen“ zu begleiten – kann nur als eine wahre Freude beschrieben werden.

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## **Anhang**

Anhang 1: Manual zum W-Seminar in der Fassung vom 03.02.2022

Die PDF-Datei steht unter dem nachfolgenden Link frei zugänglich zum Download zur Verfügung:

[https://assets.uni-augsburg.de/media/filer\\_public/e7/e6/e7e67ce1-9583-4c8e-85c3-8ace54dec6ff/manual\\_baysics\\_konsolidiert\\_-\\_stand\\_03022022.pdf](https://assets.uni-augsburg.de/media/filer_public/e7/e6/e7e67ce1-9583-4c8e-85c3-8ace54dec6ff/manual_baysics_konsolidiert_-_stand_03022022.pdf)

Anhang 2: Finale Fassung der Designprinzipien zur Erstellung der  
Lernumgebung

DG Nr.	Design Guidelines	IP Nr.	Implementation Principles	Target-Group-Specific Operationalisation
<b>Science Orientation (SO) - IBL should be oriented closely at authentic science/research</b>				
<b>SO 1</b>	IBL conceptions should provide an extensive timeframe in which a whole research cycle can be realised	<b>SO 1a</b>	IBL conceptions should contain a start-up phase to introduce students into IBL and to give an overview of the following learning process (here realized via a seminar session and a brief excursion over the course of two weeks)	<b>SO 1aI:</b> The seminar start phase should contain an introductory session to provide an overview of the seminar topic (here climate change and its regional implications), of the IBL approach, and of the following learning process (= Session A1)  <b>SO 1aII:</b> To get in touch with the seminar topic, the seminar start phase should contain a brief excursion in the students' home region to inquire selected aspects of the seminar topic (here climate change and its regional implications) with selected research methods in an exemplary manner (= Session A2)
		<b>SO 1b</b>	IBL conceptions should contain a phase that allows students to dive into the theoretical and empirical basics of the respective learning context (here realized via five seminar sessions over the course of at least six weeks, plus individual work phases in between the seminar sessions)	<b>SO 1bI:</b> The "diving into the matter"-phase should contain a learning step to postprocess the brief excursion from the seminar start phase (= Session B1, Part 1)  <b>SO 1bII:</b> The "diving into the matter"-phase should contain learning steps for students to acquire basic knowledge in the context of the seminar topic (here: causes, processes and effects of global climate change [= Session B1, Part 2 + homework + Session B2, Part 1]; regional implications of climate change for Bavaria [= Session B2, Part 2 + homework + Session B3, Part 1]; influencing factors on the individual perception of climate change [= Session B3, Part2 + homework + Session B4, Part1])  <b>SO 1bIII:</b> The "diving into the matter"-phase should contain learning steps for students to further deepen their factual knowledge about selected aspects of the seminar topic (here selected regional aspects of climate change [= Session B4, Part 2 + homework + Session B5])
		<b>SO 1c</b>	IBL conceptions should contain a phase that allows students to develop individual research questions, research methodical designs, and chronological research plans (here realized via eight seminar sessions plus two homework phases over the course of ten weeks)	<b>SO 1cI:</b> The "emergence and planning" phase should contain an initial session to discuss the goals of the students' research projects and to provide an overview over the following IBL phase (= Session C1)  <b>SO 1cII:</b> The "emergence and planning" phase should contain a session to introduce and try out relevant research methods related to the seminar topic (here geographical climate-related methods) (= Session C2)  <b>SO 1cIII:</b> The "emergence and planning" phase should contain a session to structure and narrow the students' initial topics and to introduce them into scientific literature research (= Session C3)  <b>SO 1cIV:</b> The "emergence and planning" phase should contain a homework phase for students to conduct further literature research and structuring on their individual topics (= homework phase between Session C3 and C4)  <b>SO 1cV:</b> The "emergence and planning" phase should contain a session to elaborate quality criteria for good research questions and to further structure the students' individual topics as a basis to formulate first drafts of research questions (= Session C4)  <b>SO 1cVI:</b> The "emergence and planning" phase should contain a homework phase for students to conduct formulate first drafts of individual research questions based on targeted literature research (= homework phase between Session C4 and C5)  <b>SO 1cVII:</b> The "emergence and planning" phase should contain a session to reflect, review and revise the students' research question drafts (= Session C5)  <b>SO 1cVIII:</b> The "emergence and planning" phase should contain a session to finalize the students' individual research questions and to elaborate individual methodical research designs (= Session C6)  <b>SO 1cIX:</b> The "emergence and planning" phase should contain a session to reflect, review and finalize the students' methodical research design drafts and to elaborate individual chronological research plans (= Session C7)  <b>SO 1cX:</b> The "emergence and planning" phase should contain a session to finalize the students' individual chronological research plans and to provide a transition to the following field research phase (= Session C8)
		<b>SO 1d</b>	IBL conceptions should contain a phase that allows students extensive field research activities (here realized via at least four classroom sessions plus extensive individual fieldwork over the course of about twelve to sixteen weeks)	<b>SO 1dI:</b> The field research phase should provide sufficient time to allow extensive field research activities by the students (here 2-3 months between April and July)  <b>SO 1dII:</b> The field research phase should contain a session to discuss the students' first research activities and to address potential challenges (= Session D1)  <b>SO 1dIII:</b> The field research phase should contain the occasion for individual advisory and guidance of students by the teacher (= Session D2)  <b>SO 1dIV:</b> The field research phase should contain a session for students to practice the oral communication of their individual research projects (= Session D3)  <b>SO 1dV:</b> The end of the field research phase should contain sessions for students to give interim presentations of their individual research projects (= Session D4-Dn)
		<b>SO 1e</b>	IBL conceptions should contain a phase that allows students to present their research in a written and oral form (here realized via six seminar sessions and students' individual writing over the course of at least six weeks, plus students' individual elaboration of their final presentations until the end of the seminar)	<b>SO 1eI:</b> The writing workshop phase should contain workshop sessions for students to successively review and/or develop individual elaborations of the chapters "Introduction", "Factual Basics", Research Question(s)", "Methods", "Results", and "Discussion/Conclusion" for their seminar papers with recourse to their individual field research activities (= Session E1-E6)  <b>SO 1eII:</b> The seminar conclusion phase should include time for students to prepare final presentations of their individual research projects  <b>SO 1eIII:</b> The seminar conclusion phase should contain students' final presentations of their individual research projects (= Session F1-Fn)

SO 2	IBL should at best aim at research findings that go beyond the individual learning processes and might be of common (scientific) interest	SO 2a	Research questions in IBL should at best aim at findings that are not only new for the learners themselves	<p><b>SO 2aI:</b> Session C1-C6 - Through structuring techniques, targeted literature research, and exchange with peers and the teacher, students should be encouraged to identify research gaps within their respective thematic contexts that are workable within the scope of the IBL process (here realized through: introduction and try-out of research methods, mind mapping, mutual peer-review of the mind maps, homework phases for literature research, worksheets for the structuring and narrowing of topics, mutual reflection of research questions, peer-feedback and peer-review of research question drafts, and teacher feedback)</p> <p><b>SO 2aII:</b> Session D1-D4 - Through reflection processes and exchange with peers and the teacher, students should be encouraged during the field research phase to aim at findings that have a certain degree of novelty, at least on a small regional and/or social scale (here realized through reflection and exchange of previous field work in classroom session D1 and individual advisory and guidance by the teacher in classroom session D2)</p>
		SO 2b	Written and oral communication of students' research in IBL should at best highlight potentially new insights gathered through students' research processes	<p><b>SO 2bI:</b> Session D3-D4 - In interim presentations of their individual research progress, students should be encouraged to highlight findings that potentially have a certain degree of novelty, at least on a small regional and/or social scale</p> <p><b>SO 2bII:</b> Session E2, E3, E5, E6 - During the elaboration of their seminar papers, students should be encouraged to highlight findings that potentially have a certain degree of novelty, at least on a small regional and/or social scale</p> <p><b>SO 2bIII:</b> Session F1-Fn - In the final presentations of their individual research projects in the seminar conclusion phase, students should be encouraged to highlight findings that potentially have a certain degree of novelty, at least on a small regional and/or social scale</p>
SO 3	IBL should integrate critical reflection of individual knowledge generation processes, information sources, research methods, and research results	SO 3a	IBL should include occasions for students to reflect critically on their individual knowledge generation processes	<p><b>SO 3aI:</b> Session D1 - The reflection and exchange of previous field work during the field research phase should potentially support students to reflect critically on their individual knowledge creation processes</p> <p><b>SO 3aII:</b> Session D2 - The individual advisory and guidance by the teacher during the field research phase should support students to reflect critically on their individual knowledge creation processes</p> <p><b>SO 3aIII:</b> Session D1-D4 - In the field research phase, students should be provided with an instrument to document their research activities that supports the critical reflection of their knowledge creation processes (here realized via a "researcher's logbook" plus two sample templates)</p>
		SO 3b	IBL should provide occasions for students to reflect critically on the information sources used in their individual research projects	<p><b>SO 3bI:</b> Session D2 - The individual advisory and guidance by the teacher during the field research phase should support students to reflect critically on the information sources used in their individual research projects</p> <p><b>SO 3bII:</b> Session E2, E6 - Students should be required to reflect critically on the information sources used in their individual research projects in writing their seminar papers (here realized through the elaboration of central functions and quality criteria of the chapters "Factual Basics" and "Interpretation of the Results")</p>
		SO 3c	IBL should provide occasions for students to reflect critically on the individually applied research methods and their limitations	<p><b>SO 3cI:</b> Session A2-B1 - The brief excursion during the seminar start phase should provide the opportunity to reflect on different research methods and their limitations in an exemplary manner (here realized through the common reflection and postprocessing of the excursion)</p> <p><b>SO 3cII:</b> Session C2 - The introduction to and try-out of relevant research methods during the "emergence and planning" phase should support students' reflection on different research methods and their limitations (here realized through the application of method portraits in a "gallery walk" of selected research methods)</p> <p><b>SO 3cIII:</b> Session C6-C7 - The development of methodical research designs during the "emergence and planning" phase should support students' critical reflection on the suitability and limitations of their individually applied research methods (here realized via a sample template for an adequate methodical research design plus example and via mutual reflection of students' methodical research design drafts)</p> <p><b>SO 3cIV:</b> Session D1 - The reflection and exchange of previous field work during the field research phase should potentially support students to reflect on the suitability and limitations of their individually applied research methods</p> <p><b>SO 3cV:</b> Session D2 - The individual advisory and guidance by the teacher during the field research phase should support students to reflect on the suitability and limitations of their individually applied research methods</p> <p><b>SO 3cVI:</b> Session E4 - Students should be required to reflect critically on the suitability and limitations of their individually applied research methods in writing their seminar papers (here realized through the elaboration of central functions and quality criteria of the chapter "Research Methods")</p> <p><b>SO 3cVII:</b> Session B1-Fn - During the IBL process, students should be provided with resources to support the reflection on research methods and their limitations (here realized through an online collection of method portraits)</p>
		SO 3d	IBL should require the students to reflect critically on their individual research results	<p><b>SO 3dI:</b> Session E6 - Students should be required to reflect critically on their individual research results in writing their seminar papers (here realized through the elaboration of central functions and quality criteria of the chapter "Interpretation of the Results")</p> <p><b>SO 3dII:</b> Session F1-Fn - In the final presentations of their individual research projects in the seminar conclusion phase, students should be required to communicate their individual research results in reflective manner</p>

<p><b>SO 4</b></p>	<p>IBL should draw on targeted insights into authentic science (in the sense of science carried out by professionals in the respective field)</p>	<p><b>SO 4a</b></p>	<p>IBL should aim to clarify important concepts, characteristics, and the process of knowledge production in the respective scientific discipline</p>	<p><b>SO 4aI:</b> Session A1 - The introductory session in the seminar start phase should provide a first overview of a scientific knowledge production process</p> <p><b>SO 4aII:</b> Session A2-B1 - The brief excursion in the seminar start phase and its postprocessing should provide a first glimpse of scientific means of knowledge production, while aiming to illustrate basic core characteristics of science in an exemplary manner (here realized through the exemplary application of research methods and subsequent reflection, for example regarding individual measurements that need to be linked to long-term data)</p> <p><b>SO 4aIII:</b> Session B2-B3 - The "diving into the matter"-phase should include the illustration of characteristics and concepts of scientific knowledge production (here via interactive online learning modules that address for example: particularities of climate science, or the empirical foundations on which the IPCC report is based)</p> <p><b>SO 4aIV:</b> Session B2-B3 - Students' familiarization with the factual basics of the seminar topic in the "diving into the matter"-phase should also address the reliability of scientific knowledge and the concepts of "uncertainty" and "unpredictability" in science (here via interactive online learning modules that: illustrate how increasing atmospheric CO2 levels can be attributed to human activities based on research data, reflect on a certain degree of "unpredictability" in climate science due to the complexity of the climate system, and reflect the meaning of "trust" and "uncertainty" as used in the IPCC report)</p> <p><b>SO 4aV:</b> Session B4-B5 - The "diving into the matter"-phase should allow insight into concrete examples of scientific knowledge acquisition from the scientific discipline underlying the seminar topic (here through interactive online learning modules on regional implications of climate change for Bavaria that illustrate climate-related empiry from different thematic perspectives)</p>
		<p><b>SO 5a</b></p>	<p>IBL should integrate learning steps to practice the development of research questions</p>	<p><b>SO 5aI:</b> Session C3 - The "emergence and planning" phase should include the application of structuring techniques to structure the students' initial fields of interest (here realized via mind-mapping and mutual peer-review of the mind maps)</p> <p><b>SO 5aII:</b> Session C3-C4 - The "emergence and planning" phase should include an individual work phase for students to narrow down their individual thematic contexts (here realized through the elaboration of a worksheet for the confinement of research topics in a homework phase between C3 and C4)</p> <p><b>SO 5aIII:</b> Session C4 - The "emergence and planning" phase should include common reflection on the aims and functions of a scientific research question</p> <p><b>SO 5aIV:</b> Session C4 - In the "emergence and planning" phase, central quality criteria for adequate research questions should be elaborated with the students (here realized through an information sheet that is discussed in the classroom)</p> <p><b>SO 5aV:</b> Session C4-C5 - The "emergence and planning" phase should include an individual work phase for students to develop individual research question drafts step by step, based on the elaborated criteria (here realized through the elaboration of a worksheet for the step-by-step derivation of a research question in a homework phase between C4 and C5)</p> <p><b>SO 5aVI:</b> Session C5 - The "emergence and planning" phase should include an exercise task to typologize the students' research question drafts (here realized via an information sheet that illustrates question alignment to, for example: explain sth., design sth., determine a trend of sth. . . .)</p> <p><b>SO 5aVII:</b> Session C5 - The "emergence and planning" phase should include mutual reflection of students' research question drafts and subsequent redaction of the drafts</p> <p><b>SO 5aVIII:</b> Session C5 - The "emergence and planning" phase should include criteria-based peer-review of students' research question drafts and subsequent redaction of the drafts</p> <p><b>SO 5aIX:</b> Session C5-C6 - The "emergence and planning" phase should include teacher-feedback on students' research question drafts and subsequent redaction of the drafts</p>
		<p><b>SO 5b</b></p>	<p>IBL should integrate learning steps to practice the development of methodical designs</p>	<p><b>SO 5bI:</b> Session C2 - The "emergence and planning" phase should include the introduction and try-out of research methods that are relevant in the context of the seminar topic (here realized through a gallery walk based on structured portraits of individual research methods)</p> <p><b>SO 5bII:</b> Session C6 - In the "emergence and planning" phase, quality criteria for an adequate methodical research design should be elaborated with the students (here realized through an information sheet on central criteria for an adequate methodical design that is discussed in the classroom)</p> <p><b>SO 5bIII:</b> Session C6 - The "emergence and planning" phase should include a work phase for the students to individually elaborate methodical design drafts (here realized through the elaboration of a sample template for the development of a methodical research design)</p> <p><b>SO 5bIV:</b> Session C7 - The "emergence and planning" phase should include mutual reflection of students' methodical research design drafts and subsequent redaction of the drafts</p>

SO 5	IBL should integrate learning steps to practice systematic scientific procedures	SO 5c	IBL should integrate learning steps to practice the chronological planning, organization and documentation of research activities	<p><b>SO 5cI:</b> Session C7 - The "emergence and planning" phase should include a work phase for the students to individually elaborate drafts for the chronological planning of their research activities (here realized through the elaboration of a sample template for the chronological planning of research activities)</p> <p><b>SO 5cII:</b> Session C8 - The "emergence and planning" phase should include teacher feedback on the students' chronological research plan drafts and subsequent redaction of the drafts</p> <p><b>SO 5cIII:</b> Session C8 - The "emergence and planning" phase should include a transition to the field research phase and the introduction of an instrument for the documentation of field research activities (here realized via a "researcher's logbook" plus example)</p> <p><b>SO 5cIV:</b> Session D1-D4 - During the field research phase, students should be required to systematically document their research activities using a sample template (here realized via a "researcher's logbook" plus example)</p> <p><b>SO 5cV:</b> Session D1 - To enable students to adjust the organization of their research processes, if needed, the field research phase should include reflection and exchange of previous field work experiences and the development of solution strategies for potential difficulties with peers and the teacher (here based on the students' entries in their "researcher's logbooks")</p> <p><b>SO 5cVI:</b> Session D2 - To enable students to adjust the organization of their research processes, if needed, the field research phase should include individual advisory and guidance of students by the teacher (here based on the students' chronological research plans and the entries in their "researcher's logbooks")</p> <p><b>SO 5cVII:</b> Session D4 - To enable students to adjust the organization of their research processes, if needed, the field research phase should include interim presentations of the students' research progress to highlight already accomplished intermediate goals</p>
		SO 5d	IBL should integrate learning steps to practice systematic data collection and data analysis	<p><b>SO 5dI:</b> Session A2-B1 - The brief excursion during the seminar start phase and its reflection should allow students to gain first hands-on experiences with exemplary research approaches that are commonly applied in geographical climate-related research (here: online-analysis of bark-beetle monitoring data, measurements of climate parameters, surveys with passers-by about climate-relevant questions, and observations of climate-relevant aspects in the field)</p> <p><b>SO 5dII:</b> Session D1-D4 - During their field research activities, students should extensively and systematically apply data collection methods that are commonly applied in the scientific discipline underlying the seminar topic (here geographical climate-related research)</p> <p><b>SO 5dIII:</b> Session D1-D4 - During their field research activities, students should be encouraged to apply systematic methods for data analysis that are commonly applied in the scientific discipline underlying the seminar topic (here geographical climate-related research)</p> <p><b>SO 5dIV:</b> Session D1 - To foster students' individual procedural research skills, the field research phase should include reflection and exchange of previous field work experiences and the development of solution strategies for potential difficulties with peers and the teacher</p> <p><b>SO 5dV:</b> Session D2 - To foster students' individual procedural research skills, the field research phase should include individual advisory and guidance of students by the teacher</p>
		SO 5e	IBL should integrate learning steps to practice the transparent and comprehensible written and oral communication of research projects	<p><b>SO 5eI:</b> Session D3 - The field research phase should integrate oral flash presentations for students to practice the communication of their individual research projects' interim results (here realized via a "speed dating"-exercise to communicate the key aspects of the individual research projects and the elaboration of short "pitches" to present interim results)</p> <p><b>SO 5eII:</b> Session D4 - The field research phase should integrate oral interim presentations, in which students communicate their individual research projects' interim results (here realized through individually prepared Power Point presentations)</p> <p><b>SO 5eIII:</b> Session D1-D4 - As a basis for writing their seminar papers, during the field research phase students should document their research in a way that allows them to put individual research activities in relation with individual chapters of the seminar paper (here realized via a "researcher's logbook" plus a sample template for the assignment of logbook entries, and a lesson phase to explain the assignment of logbook entries)</p> <p><b>SO 5eIV:</b> Session E1-E6 - In the writing workshop phase, central functions and quality criteria of each of the chapters of a seminar paper should be elaborated with the students (here realized through a worksheet for each of the seminar paper's individual chapters)</p> <p><b>SO 5eV:</b> Session E1-E6 - Based on the elaboration of central functions and quality criteria and with recourse to the students' documentation of their field research activities, the writing workshop phase should EITHER integrate the redaction of students' already existing drafts based on mutual peer-feedback / peer-review, OR the elaboration of drafts of each of the seminar paper's chapters (here realized through individual writing sessions for each of the seminar paper's chapters that draw on the students' individual research documentations in their "researcher's logbooks")</p> <p><b>SO 5eVI:</b> Session F1-Fn - The seminar conclusion phase should integrate a final presentation, in which students communicate their individual research projects in a transparent, comprehensible manner</p>
		SO 5f	IBL should integrate learning steps to practice targeted scientific literature research	<p><b>SO 5fI:</b> Session C3 - The "emergence and planning" phase should integrate an introduction into techniques of scientific literature research (here realized via an introduction video into scientific literature research in Session C3)</p> <p><b>SO 5fII:</b> Session C3-C5 - The "emergence and planning" phase should integrate extensive work phases for students to apply scientific literature research on their individual topics (here realized via two homework phases between Session C3 and C4, respectively C4 and C5)</p>

**Scientific Knowledge (SK) - IBL should support the acquisition and differentiation of scientific knowledge**

<b>SK 1</b>	IBL should support students to intensively immerse into and research the factual basics of the seminar topic	<b>SK 1a</b>	IBL should provide an adequate timeframe to enable students' intense immersion into the factual basics of the seminar topic	<p><b>SK 1aI:</b> Session B1-B5 - The "diving into the matter"-phase should alternate between classroom sessions and self-directed homework phases to provide students with sufficient time to familiarize themselves with the factual basics of the seminar topic (here realized via a self-directed homework phase followed by a classroom session for each of the three basic modules [Sessions B1-B4] and a homework phase to prepare the specialization modules followed by a presentation in the classroom [Session B5])</p> <p><b>SK 1aII:</b> Session C3-C5 - The "emergence and planning" phase should provide sufficient time for the students to develop a solid content knowledge in the context of their individual research projects through the application of targeted scientific literature research (here realized via two homework phases between the Sessions C3 and C4, respectively C4 and C5)</p>
		<b>SK 1b</b>	IBL should provide adequate information sources and learning materials to support students' engagement with the factual basics of the seminar topic	<p><b>SK 1bI:</b> Session B1-B5 - The "diving into the matter"-phase should provide extensive information sources and learning materials that support students' comprehension of the seminar topic's factual basics step by step (here realized via: 1) interactive online learning modules on causes, processes and effects of global climate change [= #G.01 / Session B1, Part 2 - Session B2, Part 1]; regional implications of climate change for Bavaria [= #G.02 / Session B2, Part 2 - Session B3, Part 1]; influencing factors on the individual perception of climate change [= #G.03 / Session B3, Part 2 - Session B4, Part 1]; 2) an online collection of research papers on selected topics on an appropriate level of difficulty)</p> <p><b>SK 1bII:</b> Session C3 - The "emergence and planning" phase should provide an introduction into techniques of targeted scientific literature research to support students' engagement with the factual background of their individual topics (here realized via an introduction video that explains basic techniques of targeted literature research)</p>
		<b>SK 1c</b>	IBL should include occasions to evaluate, postprocess and consolidate the students' knowledge about the factual basics of the seminar topic	<p><b>SK 1cI:</b> Session B2-B5 - The "diving into the matter"-phase should include classroom sessions to evaluate, postprocess and consolidate the knowledge that students acquire through the individual learning steps (here realized via classroom sessions to postprocess each of the three basic modules [Sessions B2-B4] and the specialization modules [Session B5])</p>
<b>SK 2</b>	IBL should integrate various occasions to support conceptual change	<b>SK 2a</b>	IBL should include occasions to make students' misconceptions visible for the teacher	<p><b>SK 2aI:</b> Session A1 - The seminar start phase should include brainstorming of students' previous knowledge about the the seminar topic (here global climate change and its regional implications)</p> <p><b>SK 2aII / = SK 2bI:</b> Session A2-B1 - The postprocessing of the brief excursion from the seminar start phase should include common reflection about potential misconceptions in the context of the exemplary inquiry activities (here for example reflections about the difference between single measurements of weather parameters and long-term climate data)</p> <p><b>SK 2aIII:</b> Session B2-B4 - The postprocessing and consolidation of basic knowledge acquired in the "diving into the matter"-phase should include common reflection about potential misconceptions in the classroom (here for example misconceptions about the causes, processes and effects of climate change on a global and regional scale, or about influencing factors on the perception of climate change)</p> <p><b>SK 2aIV:</b> Session D2 - The individual advisory and guidance of the students by the teacher during the field research phase should include reflection about potential misconceptions on a content and methodical level</p>
		<b>SK 2b</b>	IBL should provide occasions for students to experience cognitive conflicts between scientific conceptions and their own mental conceptions	<p><b>SK 2bI / = SK 2aII:</b> Session A2-B1 - The postprocessing of the brief excursion from the seminar start phase should include common reflection about potential misconceptions in the context of the exemplary inquiry activities (here for example reflections about the difference between single measurements of weather parameters and long-term climate data)</p> <p><b>SK 2bII:</b> Session B1-B4 - The "diving into the matter"-phase should convey factual basics in a way that allows students to compare them with their individual mental conceptions (here via the combination of knowledge input and interactive learning tasks in online modules that explain, for example, the role of CO2 in the absorption spectrum, or the scientific meaning of "uncertainty" of knowledge)</p> <p><b>SK 2bIII / = SK 2aIII:</b> Session B2-B4 - The postprocessing and consolidation of basic knowledge acquired in the "diving into the matter"-phase should include common reflection about potential misconceptions in the classroom (here for example misconceptions about the causes, processes and effects of climate change on a global and regional scale, or about influencing factors on the perception of climate change)</p> <p><b>SK 2bIV:</b> Session D1-D4 - To potentially allow students' mental conceptions to fail in light of their own research experiences, the field research phase should draw on the extensive and systematic use of research methods that are commonly applied in the scientific discipline underlying the seminar topic (here geographical climate-related research)</p> <p><b>SK 2bV / = SK 2aIV:</b> Session D2 - The individual advisory and guidance of the students by the teacher during the field research phase should include reflection about potential misconceptions on a content and methodical level</p>
		<b>SK 2c</b>	IBL should provide occasions for students to reconstruct their individual mental conceptions	<p><b>SK 2cI:</b> Session A1 - The brainstorming of students' previous knowledge in the seminar start phase should include common postprocessing and reconstruction of potential misconceptions</p> <p><b>SK 2cII:</b> Session A2-B1 - The postprocessing of the brief excursion from the seminar start phase should include common reconstruction of potential misconceptions</p> <p><b>SK 2cIII:</b> Session B2-B4 - The postprocessing and consolidation of basic knowledge acquired in the "diving into the matter"-phase should include common reconstruction of potential misconceptions in the classroom</p> <p><b>SK 2cIV:</b> Session D2 - The individual advisory and guidance of the students by the teacher during the field research phase should support the reconstruction of potential misconceptions</p>

**Interest- and Life-World-Oriented (IL) - IBL should be strongly oriented at the students' individual interests and life-world**

IL 1	Learning steps in IBL should pick up the students' individual interests	IL 1a	IBL should provide occasions that allow students to find individual fields of interest for their research projects	<p><b>IL 1aI:</b> Session B4 - In the "diving into the matter"-phase, students should be given the opportunity to choose individual thematic foci to deepen their factual knowledge about the seminar topic (here realized via the elaboration and presentation of two out of a total of seven specialisation modules on regional climate change: "Adaptation to climate change in cities", "Climate change and forest ecosystems", "Phenology as bioindicator for climate change", "Climate-related changes of pollen-induced health stress", "Selected approaches for climate protection in Bavaria", "Climate change and the water cycle", and "Climate change and soil ecosystems")</p> <p><b>IL 1aII:</b> Session C1 - At the beginning of the "emergence and planning" phase, students should be encouraged via the "flash response technique" to bring in their individual research interests as a basis for the following learning steps</p>
		IL 1b	The formulation of research questions should build on learning steps that pick up the students' individual interests	<p><b>IL 1bI:</b> Session C3 - After the initial steps of the emergence and planning phase, students should be supported to dive into their individual fields of interest and structure them (here realized via mind mapping of the students' individual topics and mutual peer-review of the mind maps)</p> <p><b>IL 1bII:</b> Session C3-C4 - The narrowing of the students' topics in the emergence and planning phase should be based on the structuring of their individual fields of interest (here realized through a worksheet for the confinement of research topics which picks up the students' already structured fields of interest)</p> <p><b>IL 1bIII:</b> Session C4-C5 - The criteria-based elaboration of research question drafts in the "emergence and planning" phase should pick up the students' already existing topics (here realized through a worksheet for the step-by-step derivation of a research question which picks up the students' already existing topics)</p> <p><b>IL 1bIV:</b> Session C5-C6 - The mutual reflection and peer-review of research question drafts as well as the feedback by the teacher, including the subsequent redaction, should serve to refine the students' already existing individual topics into precise, viable research questions</p>
		IL 1c	The development of methodical research designs should build on learning steps that pick up the students' individual interests	<p><b>IL 1cI:</b> Session C2 - The introduction and try-out of research methods in the initial steps of the "emergence and planning" phase should support students to assign potentially suitable methods to their individual fields of interest (here realized through a worksheet for assigning topics and methods that is elaborated during the gallery walk)</p> <p><b>IL 1cII:</b> Session C6 - The criteria-based elaboration of methodical research designs in the "emergence and planning" phase should be based on the students' already existing research questions and methodical interests (here realized through the elaboration of a sample template for the development of a methodical research design which integrates the students' already existing research questions and their individual methodical interests)</p> <p><b>IL 1cIII:</b> Session C7 - The mutual reflection of methodical design drafts and the subsequent redaction should serve to synthesize the students' already existing individual research questions and methodical considerations into viable methodical research designs</p>
		IL 1d	The development of chronological research plans should build on learning steps that pick up the students' individual interests	<b>IL 1dI:</b> Session C7-C8 - The elaboration of chronological research plans as well as the teacher feedback and the subsequent redaction should serve to translate the students' research interests and previous planning steps into viable chronological research plans
		IL 1e	The field research phase in IBL should serve the students' to conduct their individual interest-based research projects	<i>This implementation principle is realized firstly through the "emergence and planning" phase, which aligns the planning of the entire IBL process with the students' interests (see: SO 1c / IL 1a - IL 1d), and secondly through the general design of the field research phase, which allows for the implementation of the previously planned individual research projects (see: SO 1d).</i>
		IL 1f	The writing workshop phase in IBL should serve the students' to communicate their individual research projects	<i>This implementation principle is realized firstly through the "emergence and planning" phase, which aligns the planning of the entire IBL process with the students' interests (see: SO 1c / IL 1a - IL 1d), secondly through the targeted documentation of individual research activities and results during the field research phase (see: SO 5cIV / SO 5eIII), and thirdly through the general design of the writing workshop phase, which picks up on this documentation of individual research activities and results (see: SO 1eI / SO 5eV).</i>
		IL 2	IBL should integrate a complex content-area that allows students to address it from different scientific perspectives based on their individual interests	IL 2a
IL 2b	In IBL, students should be given the freedom to choose individual foci from a complex content-area			<p><b>IL 2bI:</b> Session B4-B5 - In the "diving into the matter"-phase, students should be free to choose individual foci within the defined thematic context (here realized through elective interactive online learning modules that address regional implications of climate change from different perspectives)</p> <p><b>IL 2bII:</b> Session C1-C7 - During the "emergence and planning" phase, students should be allowed to choose from a full range of potential topics within the context of the seminar topic (here regional implications of climate change) to develop individual research projects (here supported through the application of the "flash response technique" to explicate individual research interests [Session C1], as well as a gallery walk to assign research methods to freely selectable topics plus a worksheet on finding an individual research topic [Session C2])</p>

IL 3	IBL should focus on authentic problems that allow the embedding of learning processes into the complex context of everyday realities	IL 3a	Students' research in IBL should at best address questions that are meaningful for real life	<p><b>IL 3aI:</b> Session A2-B1 - The brief excursion in the seminar start phase should illustrate real-life questions in the context of the seminar topic and create a certain degree of "psychological proximity" to the topic (here realized through inquiring and reflecting selected aspects of climate change and its regional implications in the students' home regions)</p> <p><b>IL 3aII:</b> Session B3, B5 - The "diving into the matter"-phase should include content that illustrates potential questions in the context of the seminar topic that are relevant for real life (here via interactive online learning modules on: regional implications of climate change for Bavaria from different perspectives - such as climate change in Bavarian cities, phenological shifts in Bavaria, ...)</p> <p><b>IL 3aIII:</b> Session C1-C6 - The "emergence and planning" phase should allow students to develop research questions that are meaningful for real life (here potentially supported through the application of the "flash response technique" to explicate individual research interests [Session C1], as well as a gallery walk to assign research methods to freely selectable topics plus a worksheet on finding an individual research topic [Session C2])</p> <p><b>IL 3aIV:</b> Session D1-D4 - The field research phase should reduce classroom sessions to a necessary minimum to provide students with the opportunity to conduct extensive research activities in the real world</p>
		IL 3b	Students' research in IBL should at best be carried out on a local to regional scale level	<p><b>IL 3bI:</b> Session A1-A2 - The seminar start phase should integrate local to regional perspectives on climate change already from the beginning</p> <p><b>IL 3bII:</b> Session B2-B5 - The "diving into the matter"-phase should integrate regional perspectives on the seminar topic (here via interactive online learning modules on regional implications of climate change for Bavaria from different perspectives)</p> <p><b>IL 3bIII:</b> Session C1-C7 - The "emergence and planning" phase should allow students to develop research projects that are related to their home regions (here potentially supported through the application of the "flash response technique" to explicate individual research interests [Session C1], as well as a gallery walk to assign research methods to freely selectable topics plus a worksheet on finding an individual research topic [Session C2])</p> <p><b>IL 3bIV:</b> Session D1-D4 - The field research phase should allow students to carry out research activities in their own home regions</p>
		IL 3c	IBL should provide support for students to relate their research interest to their own everyday realities	<p><b>IL 3cI:</b> Session B2-B4 - The "diving into the matter"-phase should include content that relates the seminar topic to the learners' everyday realities (here interactive online learning modules on: regional implications of climate change for Bavaria, and on influencing factors on the individual perception of climate change)</p> <p><b>IL 3cII:</b> Session C1-C7 - The "emergence and planning" phase should allow students to develop research projects that are connected to their individual everyday realities (here potentially supported through the application of the "flash response technique" to explicate individual research interests [Session C1], as well as a gallery walk to assign research methods to freely selectable topics plus a worksheet on finding an individual research topic [Session C2])</p>
<b>Cooperative Research (CR) - IBL should enable to experience research as a social, cooperative process</b>				
CR 1	IBL conceptions should create various opportunities to experience research as a social, cooperative process	CR 1a	IBL should include cooperative learning activities where appropriate	<p><b>CR 1aI:</b> Session A2 - The brief excursion during the seminar start phase should be based on cooperative learning activities (here realized via the "jigsaw technique")</p> <p><b>CR 1aII:</b> Session C2 - The introduction to and try-out of relevant research methods during the "emergence and planning" phase should be conducted in group work (here realized via a "gallery walk" of research methods that is gone through by the students in tandems or small groups)</p> <p><b>CR 1aIII:</b> Session D1 - The development of solution strategies for potential difficulties during the field research phase should include common considerations and mutual collaboration (here realized via a group work phase)</p> <p><b>CR 1aIV:</b> Session E1-E6 - The sessions in the writing workshop phase should include common evaluation and reflection of sample chapters for the seminar paper (here realized through the "think-pair-share"-method to analyze sample chapters on the basis of previously elaborated quality criteria)</p>
		CR 1b	IBL should include various occasions for common and mutual reflection	<p><b>CR 1bI:</b> Session A2-B1 - The brief excursion during the seminar start phase and its postprocessing should include mutual exchange of the learning experiences and common reflection of the applied methods and gathered insights</p> <p><b>CR 1bII:</b> Session B1-B4 - The postprocessing and consolidation of acquired knowledge about the seminar topic's factual basics during the "diving into the matter"-phase should integrate common reflection phases</p> <p><b>CR 1bIII:</b> Session C4 - The development of individual research questions and methodical research designs during the "emergence and planning" phase should include common reflection of aims and functions of research questions as well as of criteria for research questions and methodical designs</p> <p><b>CR 1bIV:</b> Session D1 - The reflection of previous field work during the field research phase should include common and mutual reflection of potentially encountered difficulties</p>
		CR 1c	IBL should include constructive peer-review and peer-feedback within the learning group where appropriate	<p><b>CR 1cI:</b> Session C3, C5, C7 - The development of individual research questions and methodical research designs during the "emergence and planning" phase should integrate mutual peer-feedback and peer-review of interim products (here students' mind maps of the research topics, drafts of research questions, and drafts of methodical designs)</p> <p><b>CR 1cII:</b> Session D3 - The elaboration and application of flash presentations of the students' research projects during the field research phase should include peer-feedback</p> <p><b>CR 1cIII:</b> Session E1-E6 - The sessions in the writing workshop phase should include mutual peer-review of students' already existing chapter drafts for the seminar paper</p>

**Clarity and Transparency of the Learning Steps (CT) - IBL should be characterized by clarity and transparency of the succession, aims and functions of the learning steps to be gone through**

<b>CT 1</b>	IBL learning environments should provide clarity and transparency of the succession, aims and functions of the learning steps to be gone through	<b>CT 1a</b>	<p>In IBL conceptions, the "emergence and planning" phase, field research phase, and writing workshop phase should integrate examples of important (intermediate) products/goals of the learning processes</p> <p><b>CT 1aI:</b> Session C1 - The "emergence and planning" phase should include a vivid example for the chapter outline of a written seminar paper to provide students with a target horizon for the seminar product, to which the subsequent learning activities should finally lead (here realized via a sample template plus example)</p> <p><b>CT 1aII:</b> Session C2 - The try-out of research methods in the "emergence and planning" phase should include vivid examples for the assignment of suitable research methods to individual research topics</p> <p><b>CT 1aIII:</b> Session C1-E6 - For the elaboration, application and communication of their methodical research designs, students should be provided with vivid examples for the function and succession of the three steps of data collection, data analysis and data interpretation (here realized via an online chapter to illustrate the three steps of data collection, data analysis and data interpretation, via the sample template for the development of a methodical research design, and via the example for the chapter outline of a written seminar paper that resembles the three steps in the chapters 4, 5 and 6)</p> <p><b>CT 1aIV:</b> Session C3 - For the structuring and narrowing of their individual research interests in the "emergence and planning" phase, students should be provided with vivid examples of orientation (here realized via exemplary mind maps and orientation examples on a worksheet for the narrowing of topics)</p> <p><b>CT 1aV:</b> Session C4 - For the elaboration of individual research questions in the "emergence and planning" phase, students should be provided with vivid examples and negative examples for the formulation of a scientific research question (here realized via an information sheet on the formulation of research questions)</p> <p><b>CT 1aVI:</b> Session C5 - For the typologizing of students' research questions drafts in the "emergence and planning" phase, vivid examples for the different formulation variants should be provided (here realized via an information sheet)</p> <p><b>CT 1aVII:</b> Session C6-C7 - For the development of individual methodical research designs in the "emergence and planning" phase, students should be provided with a vivid example for an adequate methodical research design (here realized via a sample template plus example)</p> <p><b>CT 1aVIII:</b> Session C6-C8 - As a target horizon for the chronological planning of their research projects and as an overview of the learning steps to be gone through during the following field research phase, students should be provided with a vivid example for a chronological research plan (here realized via a sample template plus example)</p> <p><b>CT 1aIX:</b> Session C8-D4 - For the documentation of their research processes in the field research phase, the students should be provided with a sample template (here realized via a "researcher's logbook" plus sample template)</p> <p><b>CT 1aX:</b> Session E1-E6 - For the writing workshop phase, students should be provided with a vivid example for the chapter outline of a written seminar paper as an orientation (here realized via a sample template plus example)</p> <p><b>CT 1aXI:</b> Session E1-E6 - For the writing workshop phase, students should be provided with elaborated examples for each of the seminar paper's chapters (here realized via a worksheet for each of the chapters, respectively each of the writing workshop sessions)</p> <p><b>CT 1aXII:</b> Session B4, D4, F1-Fn - For presentations of their research progress over the course of the seminar, students should be provided with a sample template (here realized via pre-structured Power Point sample templates)</p>
		<b>CT 1b</b>	<p>In IBL, the students should be provided with an overview over the succession, aims and functions of important learning steps</p> <p><b>CT 1bI:</b> Session C1 - To foster the students' awareness of the importance of the subsequent planning steps, a reflection of the students' individual seminar objectives and perceived challenges should be integrated into the beginning of the "emergence and planning" phase of the seminar (here realized through an imaginative "time travel" to the successful conclusion of the seminar)</p> <p><b>CT 1bII:</b> Session C1-C7 - Each seminar session in the "emergence and planning" phase should include an overview of the phase's learning steps, that serves as an advance organizer and helps students understand the need for a small-step conceptualization process and the purpose of the individual learning steps (here realized via an information sheet that illustrates the individual learning steps)</p>

**Self-Direction (SD) - IBL should foster the students to self-direct their learning processes**

<b>SD 1</b>	Over the whole process, IBL should support self-direct learning to an adequate extent	<b>SD 1a</b>	IBL should foster the students' self-organization of and responsibility for their individual learning processes and support metacognition and individual reflection	<i>This implementation principle is realized through the following other design principles:</i> SO 2aI, SO 2bI - SO 2bIII SO 3aI - SO 3dII SO 4aI SO 5bIII, SO 5cI, SO 5cII, SO 5cIV, SO 5cVI, SO 5cVII, SO 5dI, SO 5dII, SO 5dIII, SO 5dV, SO 5eII, SO 5eV CT 1aI, CT 1bI, CT 1bII, CT 1aIX
		<b>SD 1b</b>	IBL should provide occasions for the students' individual elaboration of tasks and individual application of procedures	<i>This implementation principle is realized through the following other design principles:</i> SO 5aV, SO 5aVII, SO 5aVIII, SO 5aIX, SO 5bIII, SO 5bIV, SO 5cI, SO 5cII, SO 5cIII, SO 5dI, SO 5dII, SO 5dV, SO 5dVI, SO 5eI, SO 5eII, SO 5eV, SO 5eVI, SO 5fII SK1aI, SK 1aII
		<b>SD 1c</b>	IBL should foster self-direction by supporting social learning, cooperation, mutual and common reflection, and reciprocal feedback among the students	<i>This implementation principle is realized through the following other design principles:</i> SO 2aII SO 3aI, SO 3cI, SO 3cII, SO 3cIII, SO 3cIV SO 5aIII, SO 5aVII, SO 5aVIII, SO 5bI, SO 5bIV, SO 5cV, SO 5eV CR 1aI - CR 1cIII
		<b>SD 1d</b>	IBL should provide appropriate resources and learning materials to support self-directed learning processes	<i>This implementation principle is realized through the following other design principles:</i> SO 3bII, SO 3cVI, SO 3cVII, SO 3dI SO 5aIV, SO 5bII, SO 5cIII, SO 5dIV, SO 5eIII, SO 5eIV SK 1bI, SK 1bII IL 2aIV CT 1aI - CT 1aXII, CT 1bII QM 1aI - QM 1cII
		<b>SD 1e</b>	IBL should support self-direction through the introduction and demonstration of procedures and strategies, and through targeted instruction and guidance by the teacher	<i>This implementation principle is realized through the following other design principles (respectively context factors) :</i> SO 3bII, SO 3cVI, SO 3dI SO 5aIV, SO 5aVI, SO 5aIX, SO 5bI, SO 5bII, SO 5cII, SO 5cIII, SO 5cV, SO 5cVI, SO 5dIV, SO 5dV, SO 5eIII, SO 5eIV, SO 5fI GT 1aI - GT 1cI  + context factors CF 1a - CF 1d
		<b>SD 1f</b>	IBL should support self-directed learning through extensive orientation at the student's individual interests, and through other motivational strategies	<i>This implementation principle is realized through the following other design principles:</i> IL 1aI - IL 3cII CT 1aI - CT 1aXII, CT 1bI, CT 1bII QM 1bII, QM 1bIV, QM 1cI, QM 1cII

Anmerkung: Die Ausdifferenzierung der zweiten DP-Ebene des Prinzips "Selbststeuerung" ist zusammengeführt aus:  
 Brunstein & Spörer (2010): Selbstgesteuertes Lernen. In: D. H. Rost (Hrsg.), Handwörterbuch Pädagogische Psychologie, S. 751-759  
 Wüthrich (2013): Methodik des Geographieunterrichts, S. 170-175  
 Gudjons (2008): Handlungsorientiert lehren und lernen, S. 30-33  
 Hiemstra (1994): Self-directed learning. In T. Husen & T. N. Postlethwaite (Eds.), The International Encyclopedia of Education

**Quality of the Learning Materials (QM) - The Learning Materials used in IBL need to be target-oriented and appropriate**

<b>QM 1</b>	In IBL environments, learning tasks and learning materials need to be target-oriented and appropriate	<b>QM 1a</b>	In IBL processes, learning tasks and learning materials need to be oriented at the goals and purposes of the respective learning steps	<b>QM 1aI:</b> Learning tasks and learning materials need to integrate clear target expectations  <b>QM 1aII:</b> The sub-steps within learning tasks and learning materials need to be adequately structured to meet the goals of the respective learning step  <b>QM 1aIII:</b> Learning tasks and learning materials need to be adequately linked to the students' previous knowledge
		<b>QM 1b</b>	In IBL processes, learning tasks and learning materials need to be appropriate for the learning group	<b>QM 1bI:</b> Learning tasks and learning materials need to be appropriate for the age of the students  <b>QM 1bII:</b> The language used in learning tasks and learning materials needs to be comprehensible, clear and concise  <b>QM 1bIII:</b> Learning materials should be as practicable and easy to use for the students as possible  <b>QM 1bIV:</b> Learning materials should be as practicable and easy to use for the students as possible
		<b>QM 1c</b>	In IBL processes, learning materials should support the students' motivation	<b>QM 1cI:</b> Learning tasks and materials need to be aligned with the students' individual interests and their everyday realities  <b>QM 1cII:</b> Learning materials need to be designed in a vivid and motivating manner

**Guidance for Teachers (GT) - IBL conceptions should provide an adequate amount of support for the teachers**

<b>GT 1</b>	IBL conceptions should provide an adequate amount of support for the teachers to guide the students through their learning processes	<b>GT 1a</b>	IBL conceptions should support teachers with materials for information and orientation	<p><b>GT 1aI:</b> All seminar sessions - For all seminar sessions, the seminar conception should provide detailed expectation horizons for the teacher (here realized through the formulation of expectation horizons in the teacher's manual)</p> <p><b>GT 1aII:</b> All seminar sessions - For all seminar sessions, the applied learning materials and guidance measures for students should be designed to simultaneously serve teachers as an information source and to support them in guiding the students' learning processes</p> <p><b>GT 1aIII:</b> Session A1 - The introductory session in the seminar start phase should provide materials for the teacher to introduce first contents in the context of the seminar topic (here realized through Power Point slides on the definition of scientific research and on first facts about climate change in Bavaria)</p> <p><b>GT 1aIV:</b> Session A2-B1 - For the brief excursion in the seminar start phase and its postprocessing, the seminar conception should provide information materials for the teacher (here realized through Power Point slides with reflection impulses for the excursion)</p> <p><b>GT 1aV:</b> Session B2-B4 - For the postprocessing of the basic knowledge acquired by students during the "diving into the matter"-phase, the seminar conception should provide templates and information materials for the teacher (here for example realized through: a template for a classroom quiz on the basics of climate change, a Power Point presentation on an interview with a climate researcher about regional implications of climate change, and figures from the IPCC-report as information materials)</p>
		<b>GT 1b</b>	IBL conceptions should support teachers with explicit instructions, notes and suggestions	<p><b>GT 1bI:</b> All seminar sessions - For all seminar sessions, the seminar conception should provide detailed descriptions of the individual lesson steps for the teacher (here realized through the systematic description of lesson steps in the teacher's manual)</p> <p><b>GT 1bII:</b> Session C1-C7 - Particularly for the "emergence and planning" phase, the teacher should be provided with target-oriented notes and suggestions on important learning steps and how to guide them (here realized through the formulation of notes and suggestions in the teacher's manual)</p> <p><b>GT 1bIII:</b> Session D2 - For the individual advisory and guidance of the students during the field research phase, the seminar conception should provide key questions, notes and suggestions for the teacher (here realized through the description of Session D2 in the teacher's manual)</p>
		<b>GT 1c</b>	IBL conceptions should support teachers with a preceding teacher training	<p><b>GT 1cI:</b> The application of the seminar conception should be combined with a preceding teacher training to introduce the IBL conception and to prepare the teachers for the specific requirements for guiding the IBL process (here realized through a 3-days teacher training two months before the seminar start)</p>

**Context Factors (CF) - IBL processes are co-determined by context factors that can barely be influenced by the design of the learning environment**

<b>CF</b>	Important context factors / framework conditions that co-determine IBL processes	<b>CF 1</b>	In IBL, the teacher represents an important factor for the success of the learning processes	<p><b>CF 1a:</b> To successfully guide and support students throughout their inquiry-based learning processes, the teacher needs research-related competencies on the level of content knowledge, procedural and methodical skills, motivational and affective components, and organisational / planning aspects</p> <p><b>CF 1b:</b> During the whole inquiry-based learning process, the teacher should be able to support the students through adequate situational / ad-hoc guidance</p> <p><b>CF 1c:</b> During IBL processes, the teacher should take over the role of a mentor / learning companion towards the students ("guide on the side" instead of "sage on the stage")</p> <p><b>CF 1d:</b> To motivate and support the students during the IBL process, the teacher should interact with them in an appreciative, encouraging, and constructive way</p> <p><b>CF 1e:</b> During IBL processes, the teacher should be capable of effective classroom management.</p>
		<b>CF 2</b>	In IBL, the heterogeneity of the learning group represents an important context factor	<p><i>This context factor can be addressed only in parts by the design of the learning environment - here especially through the design principles regarding self-direction (see SD1) and interest- and lifeworld-orientation (see IL 1 - IL 3)</i></p> <p><i>In addition, the task falls to the teacher to support students in a heterogeneous learning group through individual, needs-based guidance (see CF 1a -CF 1d)</i></p>
		<b>CF 3</b>	In IBL, infrastructural, technical, and organisational framework conditions represent an important factor	<p><i>This context factor refers to such framework conditions as: The availability of CIP pools or authorized access to the internet to enable learning steps like online research; The seminar taking place in the late afternoon, which can influence the students' motivation; Upcoming exams in other school subjects, which can influence the students' concentration on IBL processes etc.</i></p>

Anhang 3: Übersicht über die Veränderungen der Konzeption der  
Lernumgebung zwischen den Hauptforschungszyklen

## Veränderungen der W-Seminarkonzeption zwischen den Hauptforschungszyklen

Schwarz = Elemente, die aus der Pilotversion hervorgegangen sind und Grundlage für Hauptzyklus 1 waren

Blau = Elemente, die aus Hauptzyklus 1 hervorgegangen sind und Grundlage für Hauptzyklus 2 waren

Lila = Elemente, die aus Hauptzyklus 2 hervorgegangen sind und die „finale“ Fassung bildeten, auf deren Grundlage alle weiteren Anwendungszyklen durchgeführt wurden

	Hauptzyklus 1 / 2019-2021 Manual Stand 04.02.2020	Hauptzyklus 2 / 2020-2022 Manual Stand 14.01.2021	„finale“ Fassung / 2021-2024 Manual Stand 03.02.2022
<b>Gesamtstruktur Phase C</b>	7 Sitzungen in 7 Wochen	7 Sitzungen in 8 Wochen, 2 Wochen Pause zwischen C3 und C4	8 Sitzungen in 10 Wochen, 2 Wochen Pause zwischen C3 und C4, 2 Wochen Pause zwischen C4 und C5
<b>Gesamtstruktur Unterstützung der Lehrkraft</b>	Tabellarischer Überblick über die Phase C	Tabellarischer Überblick über die Phase C	Tabellarischer Überblick über die Phase C  Kurzbeschreibung Phase C (Einführungstext) im Manual  Kurzübersicht „Phase C – Was bis wann?“ im Manual
<b>Sonstige Ergänzungen Gesamtstruktur</b>			
<b>C1 Thema</b>	Eingrenzung der Themengebiete und methodischen Zugänge für die Forschungsvorhaben der Schülerinnen und Schüler	Ziele und Elemente einer guten Forschungsplanung	Besprechung des Forschungsziels und Vorschau auf die Erstellung eines Forschungsplans
<b>C1 Kompetenzen</b>	Die SuS beschreiben die Funktionsweise einschlägiger Forschungsmethoden. [KB M]	Die SuS nennen wichtige Kapitel einer schriftlichen Forschungsarbeit und beschreiben deren Funktion. [KB M]	Die SuS nennen wichtige Kapitel einer schriftlichen Forschungsarbeit und erklären deren Funktion. [KB M]

	<p>Sie ordnen die methodischen Zugänge ihren jeweiligen Anwendungsfeldern in Bezug auf regionale Implikationen des Klimawandels zu. [KB F, M]</p> <p>Sie wählen aufgrund ihrer individuellen Interessen einen Themenbereich für ihre eigene Forschung und verbalisieren diesen. [KB K]</p>	<p>[...] → In Sitzung C2 verlagert, fällt hier weg</p> <p>[...] → In Sitzung C2 verlagert, fällt hier weg</p> <p>Sie beschreiben wichtige Elemente einer zielführenden Forschungsplanung. [KB M]</p> <p>Sie beschreiben den „Dreischritt der Datenerhebung, -auswertung und –interpretation“. [KB M]</p> <p>Sie nennen wichtige Schritte auf dem Weg zu einem fertigen Forschungsplan. [KB M]</p>	<p>[...] → fällt weg</p> <p>[...] → fällt weg</p> <p>Sie nennen wichtige Schritte auf dem Weg zu einem fertigen Forschungsplan. [KB M]</p>
<p><b>C1 Verlauf</b></p>	<p><b>Einstieg (20min):</b> Zeitreise,</p> <p><b>Erarbeitung 1 (45min):</b> Gallery Walk,</p> <p><b>Sicherung 1 (8min):</b> Regionale Implikationen d. KW und meth. Zugänge (= Sicherung Gallery Walk),</p>	<p><b>Einstieg (20min):</b> Zeitreise,</p> <p>[...] → In Sitzung C2 verlagert, fällt hier weg</p> <p>[...] → In Sitzung C2 verlagert, fällt hier weg</p>	<p><b>Einstieg (20min):</b> Zeitreise,</p>

	<p><b>Erarbeitung / Sicherung 2 (7min):</b> Eingrenzung v. Themenbereichen aus AB</p>	<p>[...] → <i>In Sitzung C2 verlagert, fällt hier weg</i></p> <p><b>Erarbeitung 1 (20min):</b> Einführung Mustergliederung + Besprechung Seminarziel,</p> <p><b>Erarbeitung 2 (20min):</b> Infoblatt Elemente einer guten Forschungsplanung + Besprechung + Beispielfahrplan,</p> <p><b>Hinführung (10min):</b> Vorbesprechung d. Planungsphase + Einführung Advance Organizer,</p> <p><b>Erarbeitung 3 (HA oder Restzeit):</b> Dreischritt der Datenerhebung + Video</p>	<p><b>Erarbeitung 1 (20min):</b> Einführung Mustergliederung + Besprechung Seminarziel,</p> <p>[...] → <i>Erarbeitung 2 entfällt</i></p> <p><b>Hinführung (20min):</b> Vorbesprechung der Planungsphase + Einführung Advance Organizer,</p> <p>[...] → <i>Erarbeitung 3 entfällt</i></p> <p><b>Erarbeitung 2 mit Sicherung (20min+):</b> Formulierung erster individueller Forschungsinteressen</p>
<p><b>C1 Materialien</b></p>	<p><b>Zeitreise (M.C1.1)</b></p> <p><b>Findung eines Themenbereichs für deine Forschung (M.C1.2)</b> + <b>Erwartungshorizont für Lehrkraft (M.C1.3)</b></p>	<p><b>Zeitreise (M.C1.1)</b></p> <p>[...] → <i>in Sitzung C2 verlagert, fällt hier weg</i></p> <p>[...]</p>	<p><b>Zeitreise (M.C1.1)</b></p>

	<p><b>Stationen Gallery Walk</b> (M.C1.4 – M.C1.15)</p>	<p>→ <i>in Sitzung C2 verlagert, fällt hier weg</i></p> <p><b>Mustergliederung zur W-Seminararbeit</b> (M.C1.2) + <b>Beispiel</b> (M.C1.3)</p> <p><b>Elemente einer guten Forschungsplanung</b> (M.C1.4)</p> <p><b>Der Dreischritt der Datenerhebung, -auswertung und -interpretation</b> (M.C1.5)</p> <p><b>In 7 Schritten zum fertigen Forschungsplan</b> (M.C1.6)</p>	<p><b>Mustergliederung zur W-Seminararbeit</b> (M.C1.2) + <b>Beispiel</b> (M.C1.3)</p> <p>[...] → „<i>Elemente einer guten Forschungsplanung</i>“ fällt weg</p> <p>[...] → „<i>Der Dreischritt der Datenerhebung, -auswertung und -interpretation</i>“ wurde ins <i>Onlinekurslabor verlagert und fällt hier weg</i></p> <p><b>In 8 Schritten zum fertigen Forschungsplan</b> (M.C1.4) → <i>Nummerierung geändert</i> → <i>Auf 8 Schritte angepasst</i></p>
<p><b>C1 Unterstützung der Lehrkraft</b></p>		<p><b>C1/Einstieg (Zeitreise):</b> “<u>Hinweis</u>: Es hat sich als förderlich gezeigt, das in der Geschichte skizzierte Szenario möglichst lebensnah wiederzugeben.“</p>	<p><b>C1/Einstieg (Zeitreise):</b> “<u>Hinweis</u>: Es hat sich als förderlich gezeigt, das in der Geschichte skizzierte Szenario möglichst lebensnah wiederzugeben.“</p> <p><b>C1/Erarbeitung 1 (Einführung Mustergliederung):</b> „<u>Hinweis</u>: In der Wissenschaft ist ein typischer „Dreischritt“ aus</p>

Datenerhebung, Datenauswertung und Ergebnisinterpretation weithin üblich. Dieser Dreischritt sollte von den SuS im Rahmen ihrer Forschungsprojekte nach Möglichkeit befolgt werden und findet sich entsprechend auch in der Mustervorlage zur Seminararbeit in den Kapiteln 4, 5 und 6 wieder. Insbesondere wird in der Wissenschaft normalerweise die Interpretation der Ergebnisse nach deren Darstellung in einem gesonderten Kapitel vorgenommen.“

**C1/Hinführung (Einführung Advance Organizer):**

„Hinweis: An dieser Stelle empfiehlt es sich erfahrungsgemäß (dies sollte aber die Lehrkraft situativ einschätzen und entscheiden), aus motivatorischen Gründen die SuS darauf hinzuweisen, dass die kommende Planungsphase eher kleinschrittig und durch ein erhöhtes Maß an Eigeninitiative geprägt ist, die es ihnen schließlich aber erlaubt, die sehr offene und selbstgesteuerte Feldforschungsphase mit dem eigenen Interessenthema erfolgreich durchzuführen.“

			<p><b>C1/Erarbeitung 2 (Formulierung Forschungsinteressen):</b>  „Hinweis: Die Themenbereiche sind durch die SuS nach ihren eigenen Interessen frei wählbar. Es kann sich also um Themen handeln, die an die Module des Onlinekurslabors anknüpfen, aber auch um weitere, selbstgewählte, solange diese im Kontext des Klimawandels auf regionaler Ebene verortbar sind.“</p>
<b>Sonstige Ergänzungen C1</b>			
<b>C2 Thema</b>	Besuch einer (Universitäts-) Bibliothek mit Einführung in die Literaturrecherche	Einführung in geeignete geographische Forschungsmethoden	Einführung in geeignete geographische Forschungsmethoden
<b>C2 Kompetenzen</b>	<p>Die SuS beschreiben grundlegende Techniken wissenschaftlicher Literaturrecherche. [KB M]</p> <p>Sie wenden erste Recherchetechniken zur Eingrenzung ihres Forschungsthemas eigenständig an. [KB M, F]</p> <p>Sie erstellen eine Mind Map zu einem selbst gewählten Themenbereich. [KB M]</p>	<p>[...] → fällt weg</p> <p>[...] → fällt weg</p> <p>[...] → fällt weg</p> <p>Die SuS beschreiben die Funktionsweise einschlägiger Forschungsmethoden. [KB M]</p>	<p>Sie beschreiben die Funktionsweise einschlägiger Forschungsmethoden. [KB M]</p>

		<p>Sie ordnen die methodischen Zugänge ihren jeweiligen Anwendungsfeldern in Bezug auf regionale Implikationen des Klimawandels zu. [KB F, M]</p> <p>Sie wählen aufgrund ihrer individuellen Interessen einen Themenbereich für ihre eigene Forschung und verbalisieren diesen. [KB K]</p> <p>→ <i>Alle aus ehemaliger Sitzung C1 übernommen und in C2 verschoben</i></p>	<p>Sie ordnen <b>unterschiedliche forschungsmethodische Zugänge möglichen Anwendungsfeldern</b> in Bezug auf regionale Implikationen des Klimawandels zu. [KB F, M]</p> <p>Sie wählen aufgrund ihrer individuellen Interessen einen Themenbereich für ihre eigene Forschung und verbalisieren diesen. [KB K]</p>
<p><b>C2 Verlauf</b></p>	<p><b>Erarbeitung 1 (85min):</b> Grundlagen der Bibliotheksbenutzung und wissenschaftlichen Literaturrecherche,</p> <p><b>Formulierung der HA (5min):</b> Aufgabe 3 auf M.C1.2 = Erstellung Mind Map</p>	<p>[...] → <i>fällt weg</i></p> <p>[...] → <i>fällt weg</i></p> <p><b>Einstieg (10min):</b> Blitzlicht zu eigenen Interessenthemen,</p> <p><b>Advance Organizer (3min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 mit Sicherung (55min):</b> Gallery Walk,</p>	<p>[...] → <i>Blitzlicht verschoben in C1</i></p> <p><b>Einstieg/Advance Organizer (5min):</b> Verortung der Sitzung</p> <p><b>Erarbeitung 1 mit Sicherung (65min):</b> Gallery Walk,</p>

		<p><b>Sicherung 1 (15min):</b> Besprechung Zuordnungsergebnisse Gallery Walk</p>	<p><b>Sicherung 1 (20min):</b> Besprechung Zuordnungsergebnisse Gallery Walk</p>
<b>C2 Materialien</b>	<p><b>Findung eines Themenbereichs für deine Forschung (M.C1.2)</b></p>	<p><b>In 7 Schritten zum fertigen Forschungsplan (M.C1.6)</b></p> <p><b>Findung eines Themenbereichs für deine Forschung (M.C2.1)</b>  → Aus C1 in C2 verschoben und Nummerierung geändert  → Aufgabe 1 geändert (statt Lückentabelle ausfüllen jetzt: Musterbeispiele für Themen-Methodenzuordnung erschließen)  → Aufgabe 2 geändert (statt Ableitung von eigenen Themen aus Lückentabelle jetzt: Analog zu Musterbeispielen aus Aufg. 1 methodische Überlegungen zu eigenen Themen anstellen)  → Aufgabe 3 (Mind Map) fällt weg</p> <p><b>Stationen Gallery Walk (M.C2.2 – M.C2.13)</b>  → Aus C1 in C2 verschoben und Nummerierung geändert</p>	<p><b>In 8 Schritten zum fertigen Forschungsplan (M.C1.4)</b></p> <p><b>Findung eines Themenbereichs für deine Forschung (M.C2.1)</b>  → Aus C1 in C2 verschoben und Nummerierung geändert  → Aufgabe 1 geändert (statt Lückentabelle ausfüllen jetzt: Musterbeispiele für Themen-Methodenzuordnung erschließen)  → Aufgabe 2 geändert (statt Ableitung von eigenen Themen aus Lückentabelle jetzt: Analog zu Musterbeispielen aus Aufg. 1 methodische Überlegungen zu eigenen Themen anstellen)  → Aufgabe 3 (Mind Map) fällt weg</p> <p><b>Stationen Gallery Walk (M.C2.2 – M.C2.13)</b>  → Aus C1 in C2 verschoben und Nummerierung geändert</p>
<b>C2 Unterstützung der Lehrkraft</b>			<p><b>C2/Einstieg (Advance Organizer):</b>  Hinweis „[→ an dieser Stelle können die in C1 notierten individuellen Themenvorschläge exemplarisch wieder aufgegriffen werden]“</p> <p><b>C2/Erarbeitung 1 (Gallery Walk):</b></p>

		<p><b>C2/Erarbeitung 1 (Gallery Walk):</b>  <b>„Hinweis:</b> Die Themenbereiche sind durch die SuS nach ihren eigenen Interessen frei wählbar. Es kann sich also um Themen handeln, die an die Module des Onlinekurlabors anknüpfen, aber auch um weitere, selbstgewählte, solange diese im Kontext des Klimawandels auf regionaler Ebene verortbar sind.“</p>	<p><b>„Hinweis:</b> In den einzelnen Methodenporträts findet sich mit Blick auf den Anwendungsbezug der jeweiligen Methode der „Dreischritt“ aus Datenerhebung, Datenauswertung und Ergebnisinterpretation wieder. Zur Orientierung befindet sich im Onlinekurlabor im Kapitel <u>#D - Der Dreischritt der Datenerhebung, -auswertung und -interpretation</u> noch einmal eine exemplarische Übersicht.“</p> <p><b>C2/Erarbeitung 1 (Gallery Walk):</b>  <b>„Hinweis:</b> Die Themenbereiche sind durch die SuS nach ihren eigenen Interessen frei wählbar. Es kann sich also um Themen handeln, die an die Module des Onlinekurlabors anknüpfen, aber auch um weitere, selbstgewählte, solange diese im Kontext des Klimawandels auf regionaler Ebene verortbar sind.“</p>
<b>Sonstige Ergänzungen C2</b>			
<b>C3 Thema</b>	Eingrenzung des Themenbereichs für die eigene Forschung als Hinführung zur Formulierung einer individuellen Forschungsfrage	Hinführung zur Formulierung von individuellen Forschungsfragen	Eingrenzung der individuellen Themenbereiche
<b>C3 Kompetenzen</b>		Sie erstellen eine Mind Map zu einem selbst gewählten	Sie erstellen eine Mind Map zu ihrem selbst gewählten Themenbereich. [KB M]

	<p>Die SuS geben ihren Mitschüler/innen Rückmeldungen zu den Mind Maps aus C2. [KB K]</p> <p>Sie analysieren einen aus der eigenen Mind Map selbst gewählten Themenbereich hinsichtlich verschiedener Eingrenzungsmöglichkeiten. [KB F, M]</p> <p>Sie stellen die Eingrenzung des eigenen Themenbereichs tabellarisch dar und erläutern diese ihren Mitschülern/innen. [KB F, M, K]</p>	<p><b>Themenbereich.</b> [KB M] → <i>Aus C2 in C3 verschoben</i></p> <p>Die SuS geben ihren Mitschüler/innen Rückmeldungen zu den Mind Maps [...]. [KB K]</p> <p>Sie analysieren einen aus der eigenen Mind Map selbst gewählten Themenbereich hinsichtlich verschiedener Eingrenzungsmöglichkeiten. [KB F, M]</p> <p>Sie stellen die Eingrenzung des eigenen Themenbereichs tabellarisch dar und erläutern diese ihren Mitschülern/innen. [KB F, M, K]</p>	<p>Sie geben ihren Mitschüler*innen Rückmeldungen zu den Mind Maps. [KB K]</p> <p><i>Sie beschreiben grundlegende Techniken und Strategien einer zielgerichteten Online-Literaturrecherche.</i> [KB M]</p> <p>Sie analysieren einen aus der eigenen Mind Map selbst gewählten Themenschwerpunkt hinsichtlich verschiedener Eingrenzungsmöglichkeiten. [KB F, M]</p> <p>Sie stellen die Eingrenzung des eigenen Themenschwerpunkts tabellarisch dar und erläutern diese ihren Mitschülern*innen. [KB F, M, K]</p>
<b>C3 Verlauf</b>	<p><b>Einstieg (10min):</b> Besprechung der Mind Maps aus der HA,</p>	<p>[...] → <i>fällt weg</i></p> <p><b>Einstieg/Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (45min):</b> Erstellung von Mind Maps,</p>	<p><b>Einstieg/Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (40min):</b> Erstellung von Mind Maps,</p>

	<p><b>Erarbeitung 1 mit TES (35min):</b> Peer Review und Ergänzung der Mind Maps,</p> <p><b>Erarbeitung 2 (45min):</b> Eingrenzung der individuellen Themen anhand M.C3.2</p>	<p><b>Erarbeitung 2 mit TES (25min):</b> Peer Review und Ergänzung der Mind Maps,</p> <p><b>Vorbereitung der HA (10min):</b> Eingrenzung der individuellen Themen (Besprechung M.C3.2, Aufg. 2)  → <i>Aus ehemaliger Erarbeitung 2 in HA verschoben</i></p>	<p><b>Erarbeitung 2 mit TES (25min):</b> Peer Review und Ergänzung der Mind Maps,</p> <p><b>Erarbeitung 3 (15min):</b> Vorbereitung einer zielgerichteten Recherche zum eigenen Themenbereich (mit M.C3.4)</p> <p><b>Vorbereitung der HA (5min):</b> Eingrenzung der individuellen Themen (Besprechung M.C3.2, Aufg. 2 + Beispielvideo zur Literaturrecherche M.C3.3)</p>
<p><b>C3 Materialien</b></p>	<p><b>Beispiel-MindMap für Lehrkraft (M.C3.1)</b></p> <p><b>Eingrenzung deines Themas (M.C3.2)</b></p>	<p><b>In 7 Schritten zum fertigen Forschungsplan (M.C1.6)</b></p> <p><b>Findung eines Themenbereichs für deine Forschung (M.C2.1)</b></p> <p><b>Beispiel-MindMap für Lehrkraft (M.C3.1)</b></p> <p><b>Eingrenzung deines Themas (M.C3.2)</b>  → <i>Aufgabenstellungen neu formuliert und präzisiert</i>  → <i>Tabelle in Aufg. 2 geändert (Spalten „Akteursgruppen“ und „Anwendungsfelder“ zusammengefasst) und präzisiert</i></p>	<p><b>In 8 Schritten zum fertigen Forschungsplan (M.C1.4)</b></p> <p><b>Findung eines Themenbereichs für deine Forschung (M.C2.1)</b></p> <p><b>Beispiel-MindMap für Lehrkraft (M.C3.1)</b></p> <p><b>Eingrenzung deines Themas (M.C3.2)</b>  → <i>Aufgabenstellung zu Aufg. 2 neu formuliert: Teilaufgaben zur gezielten Literaturrecherche mit einbezogen</i></p>

			<p><b>Beispielvideo zur Literaturrecherche (M.C3.3)</b></p> <p><b>Tipps zum Vorgehen bei der Literaturrecherche (M.C3.4)</b></p>
<p><b>C3 Unterstützung der Lehrkraft</b></p>	<p><b>C3/Einstieg:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann M.C3.1 dienen. Dort ist die Mindmap einer Schülerin zum Themenbereich „Einfluss des Klimawandels auf den osmotischen Schock bei allergenen Pollen“ zu sehen. Hieran wird deutlich, dass der Themenbereich gut strukturiert dargestellt wurde. Ein eigenes Forschungsthema kann dann nur einen auf Teilbereich daraus fokussieren.“</p> <p><b>C3/Erarbeitung 1:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann wiederum M.C3.1 dienen. Dort sind in Grün Ergänzungen einer Mitschülerin zu erkennen.“</p>	<p><b>C3/Erarbeitung 1:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann M.C3.1 dienen. Dort ist die Mindmap einer Schülerin zum Themenbereich „Einfluss des Klimawandels auf den osmotischen Schock bei allergenen Pollen“ zu sehen. Hieran wird deutlich, dass der Themenbereich gut strukturiert dargestellt wurde. Ein eigenes Forschungsthema kann dann nur einen auf Teilbereich daraus fokussieren.“</p> <p><b>C3/ Erarbeitung 2:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann wiederum M.C3.1 dienen. Dort sind in Grün Ergänzungen einer Mitschülerin zu erkennen.“</p> <p><b>Organisatorischer Hinweis:</b>          „Hinweis: Die SuS haben zur Bearbeitung insgesamt 2 Wochen Zeit (d.h. die nächste Präsenzsitzung C4 findet von heute aus gesehen erst übernächste Woche statt).“</p>	<p><b>C3/ Erarbeitung 1:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann M.C3.1 dienen. Dort ist die Mindmap einer Schülerin zum Themenbereich „Einfluss des Klimawandels auf den osmotischen Schock bei allergenen Pollen“ zu sehen. Hieran wird deutlich, dass der Themenbereich gut strukturiert dargestellt wurde. Ein eigenes Forschungsthema kann dann nur einen auf Teilbereich daraus fokussieren.“</p> <p><b>C3/ Erarbeitung 2:</b>          „Als Beispiel für die Lehrkraft zur Orientierung kann wiederum M.C3.1 dienen. Dort sind in Grün Ergänzungen einer Mitschülerin zu erkennen.“</p> <p><b>Organisatorischer Hinweis:</b>          „Hinweis: Die SuS haben zur Bearbeitung insgesamt 2 Wochen Zeit (d.h. die nächste Präsenzsitzung C4 findet von heute aus gesehen erst übernächste Woche statt).“</p>

			<p><b>C3/Vorbereitung der HA:</b>  „Die Lehrkraft stellt den SuS das Beispielvideo M.C3.3 zu zielgerichteter Online-Recherche zur Verfügung und weist darauf hin, sich dieses als Grundlage für die Hausaufgabe zuhause gewissenhaft anzusehen.  <u>Variante:</u> Alternativ kann die Lehrkraft bei ausreichender Zeit im Computerraum die Recherche zu einem Beispielthema live durchführen und dabei ggf. direkt auf Nachfragen der SuS reagieren. Das Beispielvideo M.C3.3 kann dann der Lehrkraft als Orientierung dienen.“</p> <p><b>C3/Vorbereitung der HA:</b>  „<u>Hinweis:</u> Hier bietet sich ggf. die Möglichkeit, die fertige Mind Map durch die SuS an die Lehrkraft abgeben zu lassen. Diese kann zum einen der Überprüfung des Lernfortschritts, zum anderen auch als Möglichkeit der Notenerhebung dienen.“</p>
<b>Sonstige Ergänzungen C3</b>			
<b>C4 Thema</b>	Formulierung der eigenen Forschungsfrage	Formulierung <b>einer</b> eigenen Forschungsfrage	Formulierung <b>einer</b> eigenen Forschungsfrage
<b>C4 Kompetenzen</b>	Die SuS nennen und beschreiben Kriterien für eine gute Forschungsfrage. [KB F]	Die SuS nennen und beschreiben Kriterien für eine gute Forschungsfrage. [KB F]	Sie nennen und beschreiben Kriterien für eine gute Forschungsfrage. [KB F]

	<p>Sie analysieren ihren bereits eingegrenzten Themenbereich hinsichtlich daraus resultierender Inhalts- und Fragebereiche sowie geeigneter Forschungsmethoden. [KB F, M]</p> <p>Sie entwickeln auf der Basis ihrer Analysen einen ersten Entwurf für eine eigene Forschungsfrage. [KB M, F]</p>	<p>Sie analysieren ihren bereits eingegrenzten Themenbereich hinsichtlich daraus resultierender Inhalts- und Fragebereiche sowie geeigneter Forschungsmethoden. [KB F, M]</p> <p>Sie entwickeln auf der Basis ihrer Analysen einen ersten Entwurf für eine eigene Forschungsfrage. [KB M, F]</p>	<p>Sie analysieren ihren bereits eingegrenzten Themenschwerpunkt hinsichtlich daraus resultierender Inhalts- und Fragebereiche sowie geeigneter Forschungsmethoden. [KB F, M]</p> <p>Sie entwickeln auf der Basis ihrer Analysen einen ersten Entwurf für eine eigene Forschungsfrage. [KB M, F]</p>
<b>C4 Verlauf</b>	<p><b>Einstieg (10min):</b> Begründung der Notwendigkeit einer Forschungsfrage,</p> <p><b>Erarbeitung 1 (10min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Sicherung 1 (10min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Erarbeitung 2 (35min):</b> Themenbefragung (M.C4.4/M.C4.5 „Schritte auf dem Weg zur Forschungsfrage“,</p>	<p><b>Einstieg (10min):</b> Reflexion der Notwendigkeit einer Forschungsfrage,</p> <p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (10min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Sicherung 1 (10min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Erarbeitung 2 (35min):</b> Themenbefragung (M.C4.3/M.C4.4 „Schritte auf dem Weg zur Forschungsfrage“,</p>	<p><b>Einstieg (10min):</b> Reflexion der Notwendigkeit einer Forschungsfrage, → <i>Infoblatt M.C4.1 neu integriert</i></p> <p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (15min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Sicherung 1 (10min):</b> Kriterien für eine gute Forschungsfrage,</p> <p><b>Hinführung (10min):</b> Besprechung des AB „Schritte auf dem Weg zur Forschungsfrage“ (M.C4.4),</p> <p><b>Erarbeitung 2 (30min):</b> Themenbefragung (M.C4.4/M.C4.5 „Schritte auf dem Weg zur Forschungsfrage“,</p>

	<p><b>Vertiefung (15min):</b> Reflexion der Arbeitsschritte 1-4 auf dem M.C4.4 + Ausprobieren unterschiedlicher Arten an Forschungsfragen,</p> <p><b>Sicherung 2 (10min):</b> Formulierung einer eigenen Forschungsfrage</p>	<p><b>Vertiefung (15min):</b> Reflexion der Arbeitsschritte 1-4 auf dem M.C4.3 + Ausprobieren unterschiedlicher Arten an Forschungsfragen,</p> <p><b>Sicherung 2 (10min):</b> Formulierung einer eigenen Forschungsfrage</p> <p><i>→ Zeitplanung insgesamt 5min zu viel (= 95min)</i></p>	<p>[...] → fällt weg</p> <p>[...] → fällt weg</p> <p><b>Hausaufgabe:</b> Weiterführung von M.C4.4 + Formulierung einer eigenen Forschungsfrage auf der Basis von gezielter Literaturrecherche → Vertiefung 2 und Sicherung 2 wurden hier in die HA verlagert</p>
<b>C4 Materialien</b>	<p><b>Kriterien für eine gute Forschungsfrage (M.C4.1)</b> + Vorlage zur Zuordnung der Kriterien (M.C4.2) + Lösung: Kriterien für eine gute Forschungsfrage (M.C4.3)</p>	<p><b>In 7 Schritten zum fertigen Forschungsplan (M.C1.6)</b></p> <p><b>Kriterien für eine gute Forschungsfrage (M.C4.1)</b> + Lösung/Vorlage zum Ausschneiden (M.C4.2) → Die ehemaligen M.C4.2 und M.C4.3 wurden zu einem AB zusammengefasst → Die rechte Spalte auf dem AB wurde sprachlich etwas präzisiert</p>	<p>Infoblatt „Vom Thema zur Forschungsfrage“ (M.C4.1)</p> <p><b>In 8 Schritten zum fertigen Forschungsplan (M.C1.4)</b></p> <p><b>Kriterien für eine gute Forschungsfrage (M.C4.2)</b> → Die ehemaligen M.C4.1 und M.C4.2 wurden nun nochmal zu einem einzigen AB zusammengefasst</p> <p><b>Forschungsfragen – so nicht! (M.C4.3)</b></p>

	<p>Schritte auf dem Weg zur Forschungsfrage (M.C4.4)  + Musterbeispiel für SuS (M.C4.5)  + Orientierungsbeispiel f. L. (M.C4.6)</p>	<p>Schritte auf dem Weg zur Forschungsfrage (M.C4.3)  + Musterbeispiel für SuS (M.C4.4)  + Orientierungsbeispiel f. L. (M.C4.5)</p>	<p>Schritte auf dem Weg zur Forschungsfrage (M.C4.4)  → <i>Aufgabenstellung präzisiert</i>  + Musterbeispiel für SuS (M.C4.5)  + Orientierungsbeispiel f. L. (M.C4.6)</p>
<p><b>C4 Unterstützung der Lehrkraft</b></p>		<p><b>C4/Einstieg:</b>  Impuls im Verlaufsplan unter „Unterrichtsschritte“ umformuliert</p> <p><b>C4/Einstieg:</b>  Beschreibung unter „Erwartete Ergebnisse“ präzisiert</p>	<p><b>C4/Einstieg:</b>  Impuls im Verlaufsplan unter „Unterrichtsschritte“ umformuliert</p> <p><b>C4/Einstieg:</b>  Beschreibung unter „Erwartete Ergebnisse“ präzisiert</p> <p><b>C4/Erarbeitung 1:</b>  „Hinweis: Ggf. ist es nötig, hier noch einmal die Begriffe „explizit“ und „implizit“ auf dem AB M.C4.2 zu klären.“</p> <p><b>C4/Sicherung 1:</b>  „Hinweis: Es zeigt sich, dass an dieser Stelle eine besondere Hervorhebung des Kriteriums 2 (= Erzeugung von neuem Wissen) sinnvoll ist. Der Fokus dieses W-Seminars liegt auf der eigenen empirischen Produktion von neuem Wissen – entsprechend sollten rein reproduktive Forschungsfragen, die mit bloßer Literaturrecherche bearbeitbar sind, vermieden werden.“</p>

	<p><b>C4/Erarbeitung 2:</b> „Als Beispiel für die Lehrkraft zur Orientierung kann M.C4.6 dienen.“</p>	<p><b>C4/Erarbeitung 2:</b> „Als Beispiel für die Lehrkraft zur Orientierung kann M.C4.5 dienen.“</p>	<p><b>C4/Erarbeitung 2:</b> „Als Beispiel für die Lehrkraft zur Orientierung kann M.C4.6 dienen.“</p> <p><b>C4/Erarbeitung 2:</b> „<u>Hinweis</u>: Es zeigt sich, dass in dieser Phase eine situative, individuelle Unterstützung durch die Lehrkraft gewinnbringend sein kann, um z.B. Unklarheiten und Schwierigkeiten zu begegnen, aber auch den kreativen Prozess motivierend zu unterstützen.“</p> <p><b>C4/Hausaufgabe:</b> „<u>Hinweis</u>: Es zeigt sich, dass hier die Betonung der Notwendigkeit eigenständiger Recherche sehr wichtig ist. SuS, die in die Eingrenzung des Themas sowie die Formulierung ihrer Forschungsfrage keine oder zu wenig fachliche Recherche einbringen, tun sich im Folgenden sehr schwer, zu einem konkreten, tragfähigen Forschungsplan zu gelangen.“</p>
<b>Sonstige Ergänzungen C4</b>			
<b>C5 Thema</b>	Reflexion der eigenen Forschungsfrage	Reflexion der eigenen Forschungsfrage	Reflexion <u>und Überarbeitung</u> der eigenen Forschungsfrage
<b>C5 Kompetenzen</b>	Die SuS stellen den Mitschülern/innen ihre	Die SuS stellen den Mitschülern/innen ihre	Sie stellen den Mitschülern*innen ihre Forschungsfragen vor und erläutern diese. [KB K]

	<p>Forschungsfragen vor und erläutern diese. [KB K]</p> <p>Sie geben ihren Mitschüler/innen Rückmeldungen zur Qualität von deren Forschungsfragen. [KB K, B]</p> <p>Sie überprüfen ihre eigene Forschungsfrage auf der Grundlage des Feedbacks und nehmen entsprechende Modifikationen vor. [KB M]</p> <p>Sie beurteilen die Forschungsfragen ihrer Mitschüler/innen anhand ausgewählter Kriterien. [KB B]</p>	<p>Forschungsfragen vor und erläutern diese. [KB K]</p> <p>Sie geben ihren Mitschüler/innen Rückmeldungen zur Qualität von deren Forschungsfragen. [KB K, B]</p> <p>Sie überprüfen ihre eigene Forschungsfrage auf der Grundlage des Feedbacks und nehmen entsprechende Modifikationen vor. [KB M]</p> <p>Sie beurteilen die Forschungsfragen ihrer Mitschüler/innen anhand ausgewählter Kriterien. [KB B]</p>	<p>Sie geben ihren Mitschüler*innen Rückmeldungen zur Qualität von deren Forschungsfragen. [KB K, B]</p> <p>Sie überprüfen ihre eigene Forschungsfrage auf der Grundlage des Feedbacks und nehmen entsprechende Modifikationen vor. [KB M]</p> <p>Sie beurteilen die Forschungsfragen ihrer Mitschüler*innen anhand ausgewählter Kriterien. [KB B]</p>
<b>C5 Verlauf</b>	<p><b>Erarbeitung 1 (15min):</b> Erprobung unterschiedlicher Formulierungsvariationen für die eigene Forschungsfrage,</p> <p><b>Vertiefung 1 (10min):</b> Diskursiver Austausch mit dem Sitznachbarn,</p>	<p><b>Einstieg / Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (15min):</b> Zuordnung der eigenen Forschungsfrage,  → Phase stärker auf Arbeit an der eigenen FF fokussiert (statt Ausprobieren als oftmals reine Pflichtübung nun begründete Zuordnung der eigenen Frage)  → Statt 15min Einzelarbeit nun 5min EA + 10min UG</p> <p>[...]  → Vertiefung 1 entfällt</p>	<p><b>Einstieg / Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (15min):</b> Zuordnung der eigenen Forschungsfrage,  → Phase stärker auf Arbeit an der eigenen FF fokussiert (statt Ausprobieren als oftmals reine Pflichtübung nun begründete Zuordnung der eigenen Frage)  → Statt 15min Einzelarbeit nun 5min EA + 10min UG</p> <p>[...]  → Vertiefung 1 entfällt</p>

	<p><b>Erarbeitung 2 (20min):</b> Reflexion der eigenen Forschungsfrage in Form eines „Peer-Feedbacks“,</p> <p><b>Sicherung 2 (10min):</b> Überarbeitung der Forschungsfrage,</p> <p><b>Vertiefung mit Sicherung 2 (25min):</b> Bewertung der eigenen Forschungsfrage und weitere Möglichkeit der Modifikation,</p> <p><b>Ausstieg (10min):</b> Reflexion möglicher Ängste und Hoffnungen hinsichtlich der eigenen Forschungsfrage,</p> <p><b>Abgabe der Forschungsfragen an die Lehrkraft</b></p>	<p><b>Erarbeitung 2 (20min):</b> Reflexion der eigenen Forschungsfrage in Form eines „Peer-Feedbacks“,</p> <p><b>Anwendung / Sicherung 2 (10min):</b> Überarbeitung der Forschungsfrage,</p> <p><b>Erarbeitung / Vertiefung 3 (25min):</b> Bewertung der eigenen Forschungsfrage und weitere Möglichkeit der Modifikation,</p> <p><b>[...]</b> → <i>Ausstieg zur Reflexion möglicher Ängste und Hoffnungen entfällt</i></p> <p><b>Anwendung / Sicherung 3 (15min):</b> Erneute Überarbeitung der Forschungsfrage,</p> <p><b>Abgabe der Forschungsfragen an die Lehrkraft</b></p>	<p><b>Erarbeitung 2 (20min):</b> Reflexion der eigenen Forschungsfrage in Form eines „Peer-Feedbacks“,</p> <p><b>Anwendung / Sicherung 2 (10min):</b> Überarbeitung der Forschungsfrage,</p> <p><b>Erarbeitung / Vertiefung 3 (25min):</b> Bewertung der eigenen Forschungsfrage und weitere Möglichkeit der Modifikation,</p> <p><b>[...]</b> → <i>Ausstieg zur Reflexion möglicher Ängste und Hoffnungen entfällt</i></p> <p><b>Anwendung / Sicherung 3 (15min):</b> Erneute Überarbeitung der Forschungsfrage,</p> <p><b>Abgabe der Forschungsfragen an die Lehrkraft</b></p>
<p><b>C5 Materialien</b></p>	<p><b>Typen von Forschungsfragen</b> (M.C5.1)</p> <p><b>Reflexion</b> [von Forschungsfragen] (M.C5.2)</p>	<p><b>In 7 Schritten zum fertigen Forschungsplan</b> (M.C1.6)</p> <p><b>Typen von Forschungsfragen</b> (M.C5.1)</p> <p><b>Reflexion</b> [von Forschungsfragen] (M.C5.2) → <i>Zu den Orientierungsfragen der Aufgabe wurde die Frage „Um</i></p>	<p><b>In 8 Schritten zum fertigen Forschungsplan</b> (M.C1.4)</p> <p><b>Typen von Forschungsfragen</b> (M.C5.1)</p> <p><b>Reflexion</b> [von Forschungsfragen] (M.C5.2) → <i>Zu den Orientierungsfragen der Aufgabe wurde die Frage „Um</i></p>

	<p><b>Bewertungsbogen: Kriterien für eine gute Forschungsfrage (M.C5.3)</b></p> <p><b>Beispiel eines Bewertungsbogens</b> für die Lehrkraft zur Orientierung (M.C5.4)</p> <p><b>PP-Folie mit Beispielen für zusammengefasste „Ängste und Hoffnungen“ der SuS (M.C5.5)</b></p> <p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.6)</p>	<p><i>welchen Typ Forschungsfrage handelt es sich und warum?“ hinzugefügt</i></p> <p><b>Bewertungsbogen: Kriterien für eine gute Forschungsfrage (M.C5.3)</b>  → <i>Bewertungsbogen umgestaltet: Kriterien neu formuliert und strukturiert</i></p> <p>[...]  → <i>Beispiel eines Bewertungsbogens fällt weg</i></p> <p>[...]  → <i>PP-Folie mit Beispielen für zusammengefasste „Ängste und Hoffnungen“ der SuS fällt weg</i></p> <p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.4)</p>	<p><i>welchen Typ Forschungsfrage handelt es sich und warum?“ hinzugefügt</i></p> <p><b>Bewertungsbogen: Kriterien für eine gute Forschungsfrage (M.C5.3)</b>  → <i>Bewertungsbogen umgestaltet: Kriterien neu formuliert und strukturiert</i></p> <p>[...]  → <i>Beispiel eines Bewertungsbogens fällt weg</i></p> <p>[...]  → <i>PP-Folie mit Beispielen für zusammengefasste „Ängste und Hoffnungen“ der SuS fällt weg</i></p> <p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.4)  → <i>Zu den Feedbacks auf dem Orientierungsmaterial wurden nun die zugehörigen Forschungsfragen mit hinzugefügt</i></p>
<p><b>C5 Unterstützung der Lehrkraft</b></p>	<p><b>C5/Vertiefung mit Sicherung:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann M.C5.4 dienen.“</p>	<p>[...]  → <i>Mit dem Beispiel zum Bewertungsbogen fällt auch der entsprechende Hinweis weg</i></p>	

	<p><b>C5/Abgabe der Forschungsfragen an die Lehrkraft:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann M.C5.6 dienen.“</p>	<p><b>C5/Abgabe der Forschungsfragen an die Lehrkraft:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann <a href="#">M.C5.4</a> dienen.“</p>	<p><b>C5/Erarbeitung 2:</b>  „<u>Hinweis:</u> Es zeigt sich, dass eine situative Beteiligung der Lehrkraft an den Reflexionsgesprächen – dort, wo es sinnvoll erscheint – gewinnbringend sein kann. Sie kann somit durch einzelne Impulse ggf. zur Qualität der Forschungsfragen beitragen, ohne jedoch „Bewertungsinstanz“ zu sein.“</p> <p>[...]  → <i>Mit dem Beispiel zum Bewertungsbogen fällt auch der entsprechende Hinweis weg</i></p> <p><b>C5/Erarbeitung / Vertiefung 3:</b>  „<u>Hinweis:</u> Falls es sich abzeichnen sollte, dass die SuS Schwierigkeiten bzw. Hemmungen haben, ihren Mitschülern*innen konstruktiv kritisches Feedback zu geben, sollte dies im Optimalfall durch motivierende Impulse und Tipps gezielt unterstützt werden. Die objektiven Kriterien im Bewertungsbogen bieten hierfür eine gute Grundlage.“</p> <p><b>C5/Abgabe der Forschungsfragen an die Lehrkraft:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann <a href="#">M.C5.4</a> dienen.“</p>
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Sonstige Ergänzungen C5			
<b>C6 Thema</b>	Entwicklung eines individuellen Forschungsplans (1)	Entwicklung eines individuellen forschungsmethodischen Designs	Entwicklung eines individuellen forschungsmethodischen Designs
<b>C6 Kompetenzen</b>	<p>Die SuS überarbeiten ihre individuelle Forschungsfrage auf der Grundlage eines schriftlichen Lehrerfeedbacks. [KB M]</p> <p>Sie nennen wichtige Bestandteile einer schriftlichen wissenschaftlichen Arbeit. [KB M]</p> <p>Sie nennen wichtige Bestandteile eines guten Forschungsplans. [KB M]</p> <p>Sie entwickeln einen individuellen Forschungsplan zu ihrer eigenen Forschungsfrage. [KB F, M]</p>	<p>Die SuS überarbeiten ihre individuelle Forschungsfrage auf der Grundlage eines schriftlichen Lehrerfeedbacks. [KB M]</p> <p>[...] → fällt weg</p> <p>[...] → in ähnlicher Form in C7 verlagert</p> <p>[...] → in ähnlicher Form in C7 verlagert</p> <p>Sie nennen wichtige Bestandteile eines guten forschungsmethodischen Designs. [KB M]</p> <p>Sie entwickeln ein individuelles forschungsmethodisches Design zu ihrer eigenen Forschungsfrage. [KB F, M]</p> <p>→ Zu der in C6 stattfindenden Peer-Feedback- und Überarbeitungsphase gehören eigentlich entsprechende Kompetenzziele (siehe finale Fassung,</p>	<p>Die SuS überarbeiten ihre individuelle Forschungsfrage auf der Grundlage eines schriftlichen Lehrerfeedbacks. [KB M]</p> <p>Sie nennen wichtige Bestandteile eines guten forschungsmethodischen Designs. [KB M]</p> <p>Sie entwickeln ein individuelles forschungsmethodisches Design zu ihrer eigenen Forschungsfrage. [KB F, M]</p>

		<i>C7), diese wurden aber hier im Manual nicht formuliert</i>	
<b>C6 Verlauf</b>	<p><b>Einstieg (20min):</b> Ausgabe der Feedbacks der Lehrkraft zum Entwurf der Forschungsfrage aus der vorhergehenden Stunde + Anpassung der Forschungsfrage,</p> <p><b>Hinführung (20min):</b> Mustergliederung für die schriftliche Seminararbeit,</p> <p><b>Hinführung (10min):</b> Forschungsplan,</p> <p><b>Erarbeitung + Sicherung 1 (38min):</b> Erstellung eines individuellen Forschungsplans,</p> <p>Besprechung der <b>Hausaufgabe (2min):</b> Erste Überlegungen zur Planung der Forschungsprojekte</p>	<p><b>Einstieg (20min):</b> Ausgabe der Feedbacks der Lehrkraft zum Entwurf der Forschungsfrage aus der vorhergehenden Stunde + Anpassung der Forschungsfrage,</p> <p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p>[...] → Die Einführung der Mustergliederung wurde in C1 verlagert und fällt hier weg</p> <p><b>Hinführung (10min):</b> Erstellung eines forschungsmethodischen Designs,</p> <p>[...] → Inhalte der Phase in C7 verlagert, fällt hier weg</p> <p>[...] → fällt weg</p> <p><b>Erarbeitung + Sicherung 1 (25min):</b> Erstellung eines individuellen forschungsmethodischen Designs,</p>	<p><b>Einstieg (30min):</b> Ausgabe der Feedbacks der Lehrkraft zum Entwurf der Forschungsfrage aus der vorhergehenden Stunde + Anpassung der Forschungsfrage,</p> <p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Hinführung (20min+):</b> Erstellung eines forschungsmethodischen Designs,</p> <p><b>Erarbeitung + Sicherung 1 (30min+):</b> Beginn der Erstellung eines individuellen forschungsmethodischen Designs,</p>

		<p><b>Erarbeitung 2 (10min):</b> Peer Feedback,</p> <p><b>Erarbeitung 3 (20min):</b> Überarbeitung des individuellen forschungsmethodischen Designs</p> <p>→ Die Unterrichtsphasen zur Erstellung eines Forschungsplans wurden durch solche zur Erstellung eines forschungsmethodischen Designs ersetzt</p>	<p>[...] → Die Peer-Feedbackphase wurde in C7 verlagert und fällt hier weg</p> <p>[...] → Die Überarbeitungsphase wurde in C7 verlagert und fällt hier weg</p>
<b>C6 Materialien</b>	<p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.6)</p> <p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1)</p>	<p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.4)</p> <p><b>In 7 Schritten zum fertigen Forschungsplan</b> (M.C1.6)</p> <p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1) → Abschnitt „Mein methodisches Vorgehen“ neu strukturiert mit den Schritten: „1. Auswahl &amp; Begründung des grundlegenden methodischen Ansatzes“, „2. Beschreibung &amp; Begründung des Vorgehens bei der Datenerhebung“, „3. Beschreibung &amp; Begründung des Vorgehens bei der Datenauswertung“,</p>	<p><b>Exemplarische Feedbacks zu Forschungsfragen</b> für die Lehrkraft zur Orientierung (M.C5.4)</p> <p><b>In 8 Schritten zum fertigen Forschungsplan</b> (M.C1.4)</p> <p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1) → Abschnitt „Mein methodisches Vorgehen“ neu strukturiert mit den Schritten: „1. Auswahl &amp; Begründung des grundlegenden methodischen Ansatzes“, „2. Beschreibung &amp; Begründung des Vorgehens bei der Datenerhebung“, „3. Beschreibung &amp; Begründung des Vorgehens bei der Datenauswertung“,</p>

	<p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“ (M.C6.2)</b></p> <p><b>Mustergliederung zur W-Seminararbeit (M.C6.3) + Musterbeispiel (M.C6.4)</b></p>	<p><i>„4. Weitere Überlegungen zu An- und Herausforderungen der Methodik“</i></p> <p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“ (M.C6.2)</b>  → <i>Musterbeispiele für die Forschungsfrage sowie für den „Plan bis zur Abgabe der Seminararbeit“ ersetzt und ausführlicher formuliert</i></p> <p>[...]  → <i>Die Mustergliederung wurde in C1 verlagert und entfällt hier</i></p> <p>Infoblatt <b>Kriterien für ein gutes forschungsmethodisches Design (M.C6.3)</b></p>	<p><i>„4. Weitere Überlegungen zu An- und Herausforderungen der Methodik“</i></p> <p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“ (M.C6.2)</b>  → <i>Musterbeispiele für die Forschungsfrage sowie für den „Plan bis zur Abgabe der Seminararbeit“ ersetzt und ausführlicher formuliert</i>  → <i>Jahresdaten im Beispiel-„Plan bis zur Abgabe der Seminararbeit“ wurden adaptiv formuliert (20XX statt 2019)</i></p> <p>[...]  → <i>Die Mustergliederung wurde in C1 verlagert und entfällt hier</i></p> <p>Infoblatt <b>Kriterien für ein gutes forschungsmethodisches Design (M.C6.3)</b></p>
<p><b>C6 Unterstützung der Lehrkraft</b></p>	<p><b>C6/Einstieg:</b>  „<u>Hinweis:</u> Sollten einzelne Schüler/innen zu diesem Zeitpunkt keine Überarbeitungen mehr vornehmen müssen, oder bereits vorher damit fertig sein, können diese ebenfalls ihre Mitschüler/innen beim Feinschliff derer Forschungsfragen unterstützen.“</p>	<p><b>C6/Einstieg:</b>  „<u>Hinweis:</u> Sollten einzelne Schüler/innen zu diesem Zeitpunkt keine Überarbeitungen mehr vornehmen müssen, oder bereits vorher damit fertig sein, können diese ebenfalls ihre Mitschüler/innen beim Feinschliff derer Forschungsfragen unterstützen.“</p>	<p><b>C6/ Einstieg:</b>  „<u>Hinweis:</u> Sollten einzelne SuS zu diesem Zeitpunkt keine Überarbeitungen mehr vornehmen müssen, oder bereits vorher damit fertig sein, können diese ebenfalls ihre Mitschüler*innen beim Feinschliff derer Forschungsfragen unterstützen.“</p>

	<p><b>C6/Einstieg:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann M.C5.6 dienen.)“</p> <p><b>C6/Hinführung Mustergliederung:</b>  „(→ Als Orientierung für die Lehrkraft bzw. als Unterstützung für mögliche Impulse kann hier die mit Beispielen versehene Version M.C6.4 dienen)“</p>	<p><b>C6/Einstieg:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann <a href="#">M.C5.4</a> dienen.)“</p> <p>[...]  → <i>Hinweis auf Mustergliederung fällt weg, da diese in C1 verlagert wurde</i></p>	<p><b>C6/Einstieg:</b>  „→ Als Beispiel für die Lehrkraft zur Orientierung kann <a href="#">M.C5.4</a> dienen.)“</p> <p><b>C6/Einstieg:</b>  „<u>Hinweis</u>: Impuls für SuS, falls diese mit ihrer Forschungsfrage nicht zufrieden sind: „Da du nun immer tiefer in dein Thema einsteigst und du auch mehr und mehr dazu liest, kann es sein, dass sich deine Forschungsfrage immer wieder leicht ändert - das gehört zum Forschungsprozess dazu!““</p> <p>[...]  → <i>Hinweis auf Mustergliederung fällt weg, da diese in C1 verlagert wurde</i></p> <p><b>C6/Hinführung forschungsmethodisches Design:</b>  „<u>Hinweis</u>: Auch im forschungsmethodischen Design finden sich die Schritte „Datenerhebung“ und „Datenauswertung“ aus dem in C1 und C2 bereits beschriebenen „Dreischritt“ explizit wieder, da diese für jede Methode charakteristisch</p>
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			sind und daher auch entsprechend in die Vorausplanung mit einfließen sollten.“
	<p><b>C6/allgemeiner Hinweis:</b>          „→ Bei der Erstellung und Festlegung tritt die Rolle der Lehrkraft als Mentor/Lernbegleiter besonders zu Tage. Eine angemessene individuelle Unterstützung ist ausschlaggebend für eine gute Forschungsplanung und somit das Gelingen der einzelnen Schülerforschungsprojekte.“</p>	<p><b>C6/Erarbeitung + Sicherung 1:</b>          „→ Der Lehrkraft kommt hier eine wichtige Rolle zu, denn sie sollte die einzelnen SuS bei der Ausarbeitung individuell beraten und unterstützen – insbesondere hinsichtlich der Umsetzbarkeit der individuellen Überlegungen.“</p> <p><b>C6/allgemeiner Hinweis:</b>          „→ Bei der Erstellung und Festlegung tritt die Rolle der Lehrkraft als Mentor/Lernbegleiter besonders zu Tage. Eine angemessene individuelle Unterstützung ist ausschlaggebend für eine gute Forschungsplanung und somit das Gelingen der einzelnen Schülerforschungsprojekte.“</p>	<p><b>C6/Erarbeitung + Sicherung 1:</b>          „<u>Hinweis:</u> In dieser Phase kommt der situativen, individuellen Unterstützung der SuS durch die Lehrkraft eine besondere Bedeutung zu. Die SuS sollten so selbstgesteuert wie möglich die Planung der eigenen Projekte voranbringen, dabei aber mit Tipps, Hinweisen, Erklärungen und Feedback an die Hand genommen werden, wo es nötig ist.“</p> <p>[...]          → <i>allgemeiner Hinweis fällt weg</i></p>
<b>Sonstige Ergänzungen C6</b>			
<b>C7 Thema</b>	Entwicklung eines individuellen Forschungsplans (2)	Entwicklung eines chronologischen Forschungsplans	Reflexion und Ausdifferenzierung des forschungsmethodischen Designs
<b>C7 Kompetenzen</b>			Sie entwickeln ein individuelles forschungsmethodisches Design zu ihrer eigenen Forschungsfrage. [KB F, M]

	<p>Die SuS entwickeln einen individuellen Forschungsplan zu ihrer eigenen Forschungsfrage. [KB F, M]</p> <p>Sie beschreiben wichtige Bestandteile einer guten Forschungsdokumentation. [KB M]</p>	<p>Die SuS beschreiben den Aufbau eines zielführenden chronologischen Forschungsplans. [KB M]</p> <p>Sie entwickeln einen chronologischen Forschungsplan zu ihrer eigenen Forschungsfrage. [KB F, M]</p> <p>Sie beschreiben wichtige Bestandteile einer guten Forschungsdokumentation. [KB M]</p>	<p>Sie geben ihren Mitschüler*innen Rückmeldungen zur Qualität von deren forschungsmethodischen Designs. [KB K, B]</p> <p>Sie überprüfen ihr eigenes forschungsmethodisches Design auf der Grundlage des Feedbacks und nehmen entsprechende Modifikationen vor. [KB M]</p> <p>Sie beschreiben den Aufbau eines zielführenden chronologischen Forschungsplans. [KB M]</p> <p>Sie entwickeln einen chronologischen Forschungsplan zu ihrer eigenen Forschungsfrage. [KB F, M]</p> <p>[...] → <i>Durch die Einführung einer zusätzlichen Sitzung C8 wurde die Hinführung zur Forschungsdokumentation dorthin verlagert</i></p>
<p><b>C7 Verlauf</b></p>	<p><b>Erarbeitung 1 (80min):</b> Erstellung eines individuellen Forschungsplans (Fortsetzung),</p>	<p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p><b>Erarbeitung 1 (70min):</b> Erstellung eines individuellen Forschungsplans,</p>	<p><b>Advance Organizer (5min):</b> Verortung der Sitzung,</p> <p>[...] → <i>fällt weg</i></p>

	<p><b>Sicherung 1 (3min):</b> Abgabe der Forschungsplanungen an die Lehrkraft,</p> <p><b>Hinführung (7min):</b> Forscherlogbuch</p>	<p><b>Sicherung 1 (3min):</b> Abgabe der Forschungsplanungen an die Lehrkraft,</p> <p><b>Hinführung (10min):</b> Forscherlogbuch</p>	<p>[...] → fällt weg</p> <p>[...] → fällt weg</p> <p><b>Erarbeitung 1 (15min):</b> Peer Feedback zum forschungsmethodischen Design,</p> <p><b>Erarbeitung 2 mit Sicherung (25min):</b> Überarbeitung des individuellen forschungsmethodischen Designs,</p> <p><b>Erarbeitung 3 mit Sicherung (45min):</b> Beginn der Erstellung eines chronologischen Forschungsplans</p> <p>→ <i>Durch die Einführung einer zusätzlichen Sitzung C8 wurden die Unterrichtsphasen zur Erstellung eines forschungsmethodischen Designs auf die Sitzung C7 ausgedehnt. Die Erstellung eines Forschungsplans beginnt dementsprechend nun in Sitzung C7 und erstreckt sich in Sitzung C8. Die Hinführung zum Forscherlogbuch wurde in C8 verlagert.</i></p>
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<p><b>C7 Materialien</b></p>	<p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1)</p> <p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“</b> (M.C6.2)</p> <p><b>Forschungslogbuch</b> (M.C7.1) + <b>Musterbeispiel</b> (M.C7.2)</p>	<p><b>In 7 Schritten zum fertigen Forschungsplan</b> (M.C1.6)</p> <p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1) → <i>Abschnitt „Mein methodisches Vorgehen“ neu strukturiert mit den Schritten:</i> „1. Auswahl &amp; Begründung des grundlegenden methodischen Ansatzes“; „2. Beschreibung &amp; Begründung des Vorgehens bei der Datenerhebung“; „3. Beschreibung &amp; Begründung des Vorgehens bei der Datenauswertung“; „4. Weitere Überlegungen zu An- und Herausforderungen der Methodik“</p> <p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“</b> (M.C6.2) → <i>Musterbeispiele für die Forschungsfrage sowie für den „Plan bis zur Abgabe der Seminararbeit“ ersetzt und ausführlicher formuliert</i></p> <p><b>Forschungslogbuch</b> (M.C7.1) + <b>Musterbeispiel</b> (M.C7.2)</p>	<p><b>In 8 Schritten zum fertigen Forschungsplan</b> (M.C1.4)</p> <p><b>Der „Fahrplan“ für meine Forschung</b> (M.C6.1) → <i>Abschnitt „Mein methodisches Vorgehen“ neu strukturiert mit den Schritten:</i> „1. Auswahl &amp; Begründung des grundlegenden methodischen Ansatzes“; „2. Beschreibung &amp; Begründung des Vorgehens bei der Datenerhebung“; „3. Beschreibung &amp; Begründung des Vorgehens bei der Datenauswertung“; „4. Weitere Überlegungen zu An- und Herausforderungen der Methodik“</p> <p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“</b> (M.C6.2) → <i>Musterbeispiele für die Forschungsfrage sowie für den „Plan bis zur Abgabe der Seminararbeit“ ersetzt und ausführlicher formuliert</i> → <i>Jahresdaten im Beispiel-„Plan bis zur Abgabe der Seminararbeit“ wurden adaptiv formuliert (20XX statt 2019)</i></p> <p><b>[...]</b> → <i>Das Forschungslogbuch wurde in C8 verlagert und fällt hier weg</i></p>
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<p><b>C7 Unterstützung der Lehrkraft</b></p>	<p><b>C7/Erarbeitung 1:</b>          „→ Der Lehrkraft kommt hier eine wichtige Rolle zu, denn sie sollte die einzelnen SuS bei der Ausarbeitung individuell beraten und unterstützen – insbesondere hinsichtlich der Umsetzbarkeit der individuellen Überlegungen.“</p>	<p><b>C7/Erarbeitung 1:</b>          „→ Der Lehrkraft kommt hier eine wichtige Rolle zu, denn sie sollte die einzelnen SuS bei der Ausarbeitung individuell beraten und unterstützen – insbesondere hinsichtlich der Umsetzbarkeit der individuellen Überlegungen.“</p>	<p>[...]          → <i>Hinweis in Erarbeitung 1 fällt weg</i></p> <p><b>C7/Erarbeitung 2:</b>          „<u>Hinweis</u>: In dieser Phase kommt der situativen, individuellen Unterstützung der SuS durch die Lehrkraft eine besondere Bedeutung zu. Die SuS sollten so selbstgesteuert wie möglich die Planung der eigenen Projekte voranbringen, dabei aber mit Tipps, Hinweisen, Erklärungen und Feedback an die Hand genommen werden, wo es nötig ist.“</p> <p><b>C7/Erarbeitung 3:</b>          „<u>Hinweis</u>: Es zeigt sich, dass hier gezielte Rückmeldungen der Lehrkraft zur Realisierbarkeit der individuellen Planungsschritte sinnvoll sind. Dies bezieht sich vor allem auf die Einschätzung der benötigten Zeit für bestimmte Schritte bei der Datenerhebung und -auswertung, die durch die SuS tendenziell eher zu knapp bemessen</p>
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	<p><b>C7/allgemeiner Hinweis:</b>          „→ Bei der Erstellung und Festlegung tritt die Rolle der Lehrkraft als Mentor/Lernbegleiter besonders zu Tage. Eine angemessene individuelle Unterstützung ist ausschlaggebend für eine gute Forschungsplanung und somit das Gelingen der einzelnen Schülerforschungsprojekte.“</p>	<p><b>C7/allgemeiner Hinweis:</b>          „→ Bei der Erstellung und Festlegung tritt die Rolle der Lehrkraft als Mentor/Lernbegleiter besonders zu Tage. Eine angemessene individuelle Unterstützung ist ausschlaggebend für eine gute Forschungsplanung und somit das Gelingen der einzelnen Schülerforschungsprojekte.“</p>	<p>wird. Die Lehrkraft kann diese Phase sehr gut für individuelle Beratungen nutzen.“</p> <p>[...]          → <i>allgemeiner Hinweis fällt weg</i></p>
<b>Sonstige Ergänzungen C7</b>			
<b>C8 Thema</b>			Entwicklung eines chronologischen Forschungsplans und Hinführung zur Feldforschungsphase
<b>C8 Kompetenzen</b>			<p>Sie entwickeln einen chronologischen Forschungsplan zu ihrer eigenen Forschungsfrage. [KB F, M]</p> <p>Sie beschreiben wichtige Bestandteile einer guten Forschungsdokumentation. [KB M]</p>
<b>C8 Verlauf</b>			<p><b>Advance Organizer (5min):</b>          Verortung der Sitzung,</p> <p><b>Erarbeitung 1 mit Sicherung (30min+):</b> Fertigstellung des chronologischen Forschungsplans,</p> <p><b>Hinführung (10min+):</b></p>

			<p>Ausblick auf die Feldforschungsphase D,</p> <p><b>Hinführung (10min+):</b> Forscherlogbuch</p> <p>→ Durch die Ausdehnung der Sitzungen C6 und C7 wurde eine neue Sitzung C8 eingeführt. Dort werden zunächst die Forschungspläne fertiggestellt, bevor zur Feldforschungsphase und zum darin eingesetzten Forscherlogbuch hingeführt wird.</p>
<p><b>C8 Materialien</b></p>			<p><b>In 8 Schritten zum fertigen Forschungsplan (M.C1.4)</b></p> <p><b>Der „Fahrplan“ für meine Forschung (M.C6.1)</b></p> <p>→ <i>Abschnitt „Mein methodisches Vorgehen“ neu strukturiert mit den Schritten:</i></p> <p>„1. Auswahl &amp; Begründung des grundlegenden methodischen Ansatzes“,</p> <p>„2. Beschreibung &amp; Begründung des Vorgehens bei der Datenerhebung“,</p> <p>„3. Beschreibung &amp; Begründung des Vorgehens bei der Datenauswertung“,</p> <p>„4. Weitere Überlegungen zu An- und Herausforderungen der Methodik“</p>

			<p><b>Musterbeispiel zu „Der „Fahrplan“ für meine Forschung“ (M.C6.2)</b>  → <i>Musterbeispiele für die Forschungsfrage sowie für den „Plan bis zur Abgabe der Seminararbeit“ ersetzt und ausführlicher formuliert</i>  → <i>Jahresdaten im Beispiel-„Plan bis zur Abgabe der Seminararbeit“ wurden adaptiv formuliert (20XX statt 2019)</i></p> <p><b>Forschungslogbuch (M.C8.1)</b>  + <b>Musterbeispiel (M.C8.2)</b>  → <i>Aus C7 in C8 verlagert</i></p>
<p><b>C8 Unterstützung der Lehrkraft</b></p>			<p><b>C8/Erarbeitung 1:</b>  Formulierung von zwei Varianten für die Redaktion der Planungsentwürfe:  „<u>Variante 1</u>: Die Lehrkraft sieht sich die einzelnen Entwürfe im Anschluss an die Sitzung an und nimmt ggf. letzte Korrekturen vor (→ Überarbeitungsvorschläge und Kommentare im Word-Dokument mit der Funktion „Änderungen nachverfolgen“). Jede/r SuS bekommt seinen korrigierten Forschungsplan per E-Mail zugeschickt und kann auf dieser Grundlage mit der Feldforschungsphase beginnen.“  „<u>Variante 2</u>: Die Lehrkraft sieht sich die einzelnen Entwürfe im Anschluss</p>

			<p>an die Sitzung an und nimmt ggf. letzte Korrekturen vor. Schließlich findet für jede/n S/S auf dieser Grundlage ein kurzes individuelles Beratungsgespräch mit der Lehrkraft statt, in welchem ein verbindlicher Forschungsplan je S/S für die folgenden Seminarphasen festgehalten wird.“</p> <p><b>C8/Erarbeitung 1:</b>  „<u>Hinweis</u>: Es kann an dieser Stelle sinnvoll sein, den SuS zu kommunizieren, dass der nun erstellte Forschungsplan zwar ein wichtiges Planungs- und Orientierungsdokument für den gesamten weiteren Forschungsverlauf dar-stellt (und daher eine Ausarbeitung in dieser Detailliertheit wichtig ist), dieser aber nicht zwingend „in Stein gemeißelt ist“. Im Laufe v.a. der Feldforschungsphase kann es immer wieder zu kleineren dynamischen Anpassungen des Plans kommen, wo diese sinnvoll sind. Dies ist auch in der Wissenschaft üblich.“</p>
<p><b>Sonstige Ergänzungen C8</b></p>			