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## **ENHANCING EDUCATIONAL QUALITY IN METEOROLOGY AND CLIMATOLOGY THROUGH A BLENDED LEARNING FRAMEWORK**

***Abstract:** This paper examines the integration of a blended learning framework to enhance the quality of education in meteorology and climatology. The study explores the design and implementation of this framework in meteorology and climatology education, focusing on its ability to improve accessibility, student engagement, and learning outcomes. Through case studies and analysis, the paper highlights the benefits of blended learning, such as increased student motivation, personalized learning experiences, and the development of critical skills necessary to address climate change challenges.*

***Key words:** blended learning, flipped learning, student engagement, meteorology and climatology education*

***Анотація:** У статті досліджено інтеграцію моделі змішаного навчання для підвищення якості освіти в галузі метеорології та кліматології.*

*Дослідження зосереджено на проектуванні та впровадженні цієї моделі в освіті з метеорології та кліматології, з акцентом на її здатність покращувати доступність, залучення студентів та результати навчання. Через приклади та аналіз стаття підкреслює переваги змішаного навчання, такі як підвищення мотивації студентів, персоналізовані навчальні досвіди та розвиток критичних навичок, необхідних для вирішення проблем, пов'язаних з кліматичними змінами.*

**Ключові слова:** *змішане навчання, перевернуте навчання, залучення студентів, освіта з метеорології та кліматології.*

## **1. Introduction to Blended Learning**

Blended learning is an educational approach that integrates traditional face-to-face instruction with online learning activities, creating a cohesive and flexible learning experience. It combines classroom teaching with digital resources to enhance student engagement and accessibility within the same course. Blended learning is often described as a “thoughtful fusion of face-to-face and online learning experiences” [1]. Additionally, blended programs may offer a mix of fully online and in-person courses, allowing students to engage with different modes of learning across their curriculum.

Blended learning has continuously evolved alongside technological advancements, transforming the way education is delivered. The roots of distance education date back to the 19th century with correspondence courses, which allowed students to study independently via mail. These early methods of education helped expand access to learning beyond traditional classrooms and set the stage for modern distance learning and blended learning practices.

As new technologies emerged, learning became increasingly interactive and accessible. Radio and television played a key role in making education more engaging by offering audio and visual content remotely, thus broadening the scope of what could be taught. These innovations laid the groundwork for the evolution of blended learning by integrating new media into the educational process, blending traditional face-to-face methods with more interactive and remote elements.

The development of blended learning is closely tied to technological progress and evolving teaching strategies. In the 1960s, mainframe computers introduced the first structured, computer-based learning systems, marking the beginning of digital education. By the 1980s, Learning Management Systems (LMS) emerged, offering teachers and students new ways to interact with course materials, fostering a more flexible and interactive learning environment. The shift from passive, lecture-based learning to more active, learner-centered experiences began with the introduction of these systems.

A pivotal moment occurred in 1998 with the rise of web-based instruction, which made learning materials more widely accessible. Teachers began to see the potential

for combining classroom instruction with digital tools, enhancing student engagement and providing more diverse learning experiences. This era marked a significant turning point, as the internet opened up vast resources, enabling the integration of multimedia, discussion forums, and real-time collaboration tools into traditional learning settings.

In the 2000s, hybrid learning models gained popularity, as educational institutions embraced the combination of online and in-person learning. This model offered flexibility in how content was delivered and allowed for a broader range of teaching and learning styles, including flipped classrooms where students first encounter content online and then engage in interactive discussions during face-to-face sessions. As mobile learning technologies expanded in the 2010s, education became even more accessible, allowing learners to engage with course content on a variety of devices from anywhere in the world, thus supporting lifelong learning and just-in-time learning.

## **2. Benefits and Challenges of Blended Learning**

Blended learning offers numerous advantages, making education more flexible and accessible. It allows students to learn at their own pace, engaging with materials anytime and anywhere. By integrating digital tools, multimedia content, and interactive activities, it enhances student engagement and accommodates different learning styles. The combination of online and in-person instruction reinforces knowledge retention, while adaptive learning technologies enable personalized education. Additionally, blended learning can be cost-effective, reducing the need for extensive physical infrastructure while broadening access to quality education. It also helps students and educators develop digital skills essential for modern professional environments. Furthermore, online discussion forums and collaborative platforms foster peer interaction and teamwork, creating a more dynamic learning experience.

However, blended learning also presents challenges that must be addressed for effective implementation. Technological barriers remain a significant issue, as not all students or institutions have reliable internet access or adequate devices. Educators often require additional training to effectively integrate digital tools into their teaching, and students must develop strong self-discipline and time management skills to stay engaged with online learning components. If not properly designed, blended learning can reduce student-teacher and peer interactions, impacting the overall learning experience. Assessing student performance and maintaining academic integrity in online settings can also be complex. Additionally, some educators and students may resist the shift from traditional teaching methods, preferring face-to-face instruction. Technical issues, such as software malfunctions or connectivity problems, can further disrupt the learning process.

Despite these challenges, blended learning remains a powerful approach to modern education, offering innovative ways to enhance learning experiences when carefully planned and implemented.

### **3. Case Studies and Applications**

Blended learning has become an effective approach in meteorology and climatology education, integrating digital tools with practical, hands-on instruction. This approach enhances accessibility, engagement, and skill development, particularly in fields that require both theoretical knowledge and applied expertise. Several initiatives exemplify the successful implementation of blended learning in climate science education.

One notable example is Project Climandes in the Andean region, which addresses geographic and logistical challenges by combining online and face-to-face learning [2]. The online component includes recorded lectures, interactive simulations, and quizzes, enabling students to learn at their own pace. In-person workshops provide opportunities for practical applications, case study discussions, and expert collaboration. Virtual weather stations and data analysis software further enrich hands-on learning. This model has proven to be a scalable and cost-effective solution for climatology education, equipping students with essential skills to address regional climate challenges.

Another successful application is the Geographical Education Studies Program [3], which redefines traditional meteorology and climatology courses at the university level. Instead of relying solely on lectures and textbooks, the program integrates online lectures, discussion forums, and multimedia resources such as videos, podcasts, and e-learning modules to accommodate different learning styles. Face-to-face sessions focus on applying theoretical knowledge through data analysis, field trips, and activities like weather forecasting and climate modeling. This hybrid structure enhances student engagement, improves comprehension, and strengthens both theoretical and practical competencies.

Blended learning is also central to the Blended MSC/COMET Winter Weather Course [4], which enhances the understanding of winter weather forecasting for meteorologists and forecasters. Online modules, webinars, and interactive polls prepare students before in-person sessions, where they engage in hands-on labs using unconventional methods such as Play-Doh modeling and interpretive exercises to visualize atmospheric processes. Group discussions reinforce forecasting concepts and explore workflow optimization in weather services. By combining the flexibility of online learning with the interactivity of in-person instruction, the course improves forecasting skills and strengthens winter storm preparedness.

The Managing for a Changing Climate course at the University of Oklahoma [5] employs a similar blended learning model, using pre-recorded videos, readings, and

digital resources for asynchronous learning. Synchronous discussions and collaborative exercises foster deeper engagement. The course incorporates a learning management system, video production tools, and interactive platforms to enhance student participation. Discussion forums and real-time collaboration tools facilitate peer learning, while data visualization software aids in climate analysis. Designed as an interdisciplinary program, it prepares students to critically assess climate issues and develop informed solutions.

It should be noted, that the integration of advanced technologies played a crucial role in enhancing the effectiveness of blended learning in meteorology and climatology education. Tools such as weather simulation software, Geographic Information Systems (GIS), and data analysis platforms like MATLAB, Python, and R are increasingly being used to provide students with practical experiences that mirror real-world applications. Weather simulation software allows students to analyze and predict weather patterns, while GIS and other geospatial technologies enable them to explore climate data and visualize environmental changes. These tools are essential for helping students understand the spatial and temporal aspects of climatology. By using such technologies, students develop valuable skills that are directly applicable to professional work in meteorology, climatology, and related fields. These tools also make learning more engaging, as they allow students to work with data and simulations that are closely tied to the real-world challenges faced by meteorologists and climatologists.

#### **4. Implementing Blended Learning Frameworks**

##### *4.1. Blended Learning Framework*

The blended learning approach typically follows a flipped classroom model, where students engage with pre-recorded lectures, readings, and interactive materials before attending live sessions. This structure allows classroom time to be used more effectively for discussions, collaborative problem-solving, and practical applications.

Within the framework of flipped-learning approaches, a wide variety of approaches and designs with both large and small class sizes are being applied. The flipped learning approach has many of the benefits of the other active learning approaches but is along with simpler to implement since much of the content needed for the flipped approach will have already been developed for a standard lecture-based module. Many meteorological and climatological education and training modules operate on a very similar model to flipped learning, with extensive workshops and seminars, so moving to this model of teaching requires only limited changes to module structure. Flipped learning also doesn't require the module designer to change the assessment for the module (unlike, for example, problembased or enquiry-based learning).

Under the implementation of flipped learning, the course is organized into thematic modules, each consisting of:

- **Pre-class activities** (asynchronous): Readings, instructional videos, quizzes, and case studies.
- **Live sessions** (synchronous): Instructor-led discussions, group work, and interactive exercises.
- **Post-class assessments** (asynchronous): Assignments, reflection exercises, and peer feedback activities.

This framework supports **active learning** through case studies, simulations, and problem-based learning while ensuring accessibility and flexibility.

#### 4.2. *Course Structure and Instructional Design*

The course is designed with a structured approach, grounded in Gagné's Nine Events of Instruction, to ensure effective knowledge acquisition and engagement. This model provides a step-by-step guide through the learning process, starting with gaining attention, presenting objectives, and moving through content delivery, practice, and assessment, ensuring students are fully supported at every stage. The design fosters a logical progression, helping students connect theoretical concepts with their practical applications.

To maximize engagement and learning, the course employs several key instructional strategies:

- **Collaborative Learning:** Discussion forums, peer feedback, and group projects create an interactive learning environment. These collaborative elements not only facilitate deeper understanding but also encourage students to apply their knowledge in diverse contexts, fostering a sense of community and active participation.

- **Adaptive Learning Pathways:** The course is designed to be flexible, allowing students to progress at their own pace. This adaptability is critical for accommodating different learning styles, needs, and schedules, providing opportunities for students to master concepts before moving on to more advanced material.

- **Universal Design for Learning (UDL):** To ensure accessibility for all students, the course integrates a variety of content formats, such as text, video, and interactive media. UDL principles allow students to engage with the material in ways that best suit their individual learning preferences, enhancing understanding and retention.

The course emphasizes the practical application of knowledge through real-world case studies, simulations, and hands-on exercises relevant to the subject matter. These activities bridge the gap between theory and practice, helping students to not only grasp key concepts but also to develop critical thinking and problem-solving skills. The design of the course ensures that students are actively engaged, motivated,

and provided with the tools necessary for success in both academic and professional contexts.

#### 4.3. *Digital Tools and Learning Management System*

The course is supported by a range of digital tools and platforms that enhance the blended learning experience and provide students with a seamless, interactive environment for learning. These tools are carefully integrated to support various aspects of the course, from content delivery and communication to collaboration and assessment.

- **Moodle:** As the primary Learning Management System (LMS), Moodle serves as the central hub for hosting course materials, assignments, quizzes, and discussion forums. It allows students to easily access all resources and track their progress, while providing instructors with tools for grading, monitoring engagement, and facilitating communication. Moodle also supports the integration of various plugins and multimedia content, ensuring a rich learning environment.

- **Zoom / Microsoft Teams:** These tools are used for virtual sessions, including live lectures, office hours, and group work. Zoom and Microsoft Teams enable real-time interaction, making it possible for students and instructors to engage in synchronous discussions, collaborate on projects, and ask questions. These platforms also facilitate peer-to-peer communication and foster a sense of community in an online setting, ensuring that students can access support and connect with their peers during the course.

- **H5P and SCORM Packages:** For interactive content and self-paced learning, H5P and SCORM packages are integrated into the course design. These tools allow the creation of interactive multimedia elements such as quizzes, interactive videos, drag-and-drop activities, and more. They support active learning by engaging students with dynamic content that can be tailored to individual learning needs and paced appropriately.

- **Google Docs, Miro, Padlet:** These tools enable real-time collaboration and knowledge sharing. Google Docs allows for shared document editing, making it ideal for group projects and collaborative assignments. Miro and Padlet are used for brainstorming, idea mapping, and interactive discussions. These platforms foster creativity and allow students to collaborate in real time, regardless of their location.

- **Turnitin and Grammarly:** To support academic writing and maintain academic integrity, Turnitin and Grammarly are integrated into the course. Turnitin helps prevent plagiarism by comparing student submissions with a vast database of academic sources, ensuring originality. Grammarly assists students with grammar, spelling, punctuation, and style, helping them improve the quality of their writing and produce polished assignments.

These digital tools work together to create a cohesive and efficient learning environment, promoting interaction, collaboration, and feedback. They facilitate communication between students and instructors, support various learning activities, and ensure that students have the resources they need to succeed in their academic journey. The combination of these platforms ensures that the blended learning experience is engaging, accessible, and effective, supporting both individual learning and group-based activities.

## **5. Summary**

This paper discusses the implementation of a blended learning framework to enhance the quality of education in meteorology and climatology. Blended learning, which combines online and face-to-face learning experiences, offers numerous advantages, including increased flexibility, accessibility, and personalized learning opportunities. It allows students to engage with pre-recorded lectures, interactive materials, and readings before attending live sessions, making classroom time more focused on discussions, collaborative problem-solving, and practical applications.

The course is structured using a flipped classroom model, incorporating pre-class asynchronous activities, synchronous live sessions, and post-class assessments. Instructional design follows Gagné's Nine Events of Instruction, ensuring a logical sequence that guides students through key concepts and applications. Collaborative learning, adaptive learning pathways, and Universal Design for Learning (UDL) principles are integrated to support diverse learning styles and promote engagement.

Digital tools, including Moodle, Zoom, H5P, Google Docs, and Turnitin, are leveraged to enhance the learning experience. These platforms facilitate content delivery, real-time collaboration, interactive exercises, and academic support, ensuring a seamless and effective learning environment. The blended learning framework not only improves student engagement and knowledge retention but also aligns with real-world applications through the use of simulations, case studies, and hands-on exercises.

By adopting this blended learning model, meteorology and climatology education becomes more accessible, flexible, and engaging, ultimately enhancing learning outcomes and fostering the development of critical skills needed to address global climate challenges. In the paper this is demonstrated through four examples of the successful implementation of this approach in the field of meteorology and climatology.

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